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FM 6-40

DEPARTMENT OF THE ARMY FIELD MANUAL

FIELD ARTILLERY CANNON GUNNERY

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FIELD ARTILLERY CANNON GUNNERY

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PART ONE

GENERAL

CHAPTER 1

INTRODUCTION

Section I. GENERAL

1. Purpose

This manual explains the field artillery cannon gunnery problem and presents a practical application of the science of ballistics and of procedures essential for the timely delivery of effective artillery fire. This manual is a guide and cannot cover all situations. Local situations may dictate modification of the methods and techniques described herein. Modifications can be made based on the knowledge of the gunnery supervisor and the state of training of the unit personnel. Any modification should result in a gain in either accuracy or speed or both. Any modification which results in the degradation of either should be seriously questioned.

2. Scope

This manual encompasses all aspects of field artillery gunnery for cannons. The material presented herein is applicable without modification to both nuclear and nonnuclear warfare. The scope includes—

- a. Characteristics and capabilities of weapons and ammunition.
- b. Fundamentals of ballistics.
- c. Firing battery gunnery.
- d. Observer procedures.
- e. Fire direction.
- f. Miscellaneous gunnery information.

3. Changes or Corrections

Users of this manual are encouraged to submit recommended changes or comments to improve the manual. Comments should be keyed to the specific page, paragraph, and line of the text in which change is recommended. Reasons should be provided for each comment to insure understanding and complete evaluation. Comments should be forwarded direct to U.S. Army Artillery and Missile School.

4. References

See appendix I for list of references.

5. The Field Artillery Gunnery Problem

Field artillery weapons are normally emplaced in defilade so that they cannot be easily located by the enemy. For the vast majority of targets, placing pieces in defilade precludes sighting the weapon directly at the target (direct fire). Consequently, a method called indirect fire must be employed. The gunnery problem is primarily the problem of indirect fire. The solution of this problem requires weapon and ammunition settings which, when applied to the pieces and the ammunition, will cause the projectile to burst at, or at a proper height above, the target. The steps in the solution of the gunnery problem are—

- a. Location of the target.
- b. Determination of chart data (direction, range, and vertical interval from weapons to target).
- c. Conversion of chart data to firing data.
- d. Application of firing data to the weapons.

6. Field Artillery Gunnery Team

The coordinated efforts of the field artillery gunnery team are required to accomplish the solution of the gunnery problem outlined in paragraph 5. The elements of the team must be interconnected by an adequate communications system. The elements of the gunnery team are—

- a. *Observers.* The observers detect and report the location of suitable targets, request fire, and conduct an adjustment if necessary.
- b. *Fire Direction Center.* The fire direction center (FDC) determines firing data and furnishes these data in the form of fire commands to the firing battery.

c. *Firing Battery.* The firing battery applies the firing data to the weapons and fires the weapons. The firing battery is the fire unit for field artillery.

7. Basic Principles of Employment of Field Artillery Firepower

a. Field artillery doctrine demands the timely and accurate delivery of fire to meet the requirements of supported troops. All members of the artillery team must be continuously indoctrinated with a sense of urgency. They must strive to reduce by all possible measures the time required to execute an effective fire mission.

b. To be effective, artillery fire of suitable density must hit the target at the proper time and with the appropriate projectile and fuze.

c. Good observation permits delivery of the most effective fire. Limited observation results in a greater expenditure of ammunition and reduces the effectiveness of fire. Some type of observation is desirable for every target fired on in order to insure that fire is placed on the target. Observation of close-in battle areas is usually visual. When targets are hidden by terrain features or when greater distances or limited visibility are involved, observation may be either visual (air or flash) or electronic (radar or sound). When observation is available, corrections can be made to place artillery fires on target by adjustment procedures; however, lack of observation must not preclude firing on targets that can be located by other means. For targets that cannot

be observed, effective fire must be delivered by unobserved fire procedures.

d. Field artillery fires must be delivered by the most accurate means which time and the tactical situation permit. When possible, survey will be used to locate the gun (howitzer) position and targets accurately. Under some conditions, only a rapid estimate of the relative location of weapons and targets may be possible. However, survey of all installations should be as complete as time permits in order to achieve the most effective massed fires. Inaccurate fire wastes ammunition and reduces the confidence of supported troops in their artillery support.

e. In order to inflict a maximum number of casualties, the immediate objective is to deliver a mass of accurate and timely fire. The number of casualties inflicted in a specific target area can be increased in most instances by surprise fire. If surprise massed fires cannot be achieved, the time required to bring effective fire to bear on the target should be reduced to the minimum.

f. The greatest demoralizing effect on the enemy can be achieved by delivering a maximum number of rounds from many pieces in the shortest possible time and without adjustment. Accurate massed fire with 1 round per weapon from 6 batteries will be much more effective than 6 rounds per weapon from 1 battery, provided that all rounds arrive on the target simultaneously.

g. Artillery units must be prepared to handle multiple fire missions when the situation so dictates.

Section II. FIELD ARTILLERY CANNONS

8. General

a. Field artillery cannons are classified according to caliber and maximum range capability as light, medium, heavy, and very heavy.

(1) *Light*—120-mm and less.

(2) *Medium*—Greater than 120-mm, but not to exceed 160-mm.

(3) *Heavy*—Greater than 160-mm, but not to exceed 210-mm.

(4) *Very heavy*—Greater than 210-mm.

b. Field artillery cannons also are classified according to their method of organic transportation.

(1) *Towed*—Cannon designed for movement as trailed loads behind prime movers. This includes weapons transported in single or multiple loads and *weapons transported in a single load by multiple prime movers.*

(2) *Self-propelled*—Cannon permanently installed on vehicles which provide motive power for the piece and from which the weapon is fired.

(3) *Aeropack*—Cannon designed for transport, assembled or in sections, by Army

aircraft. The weapon and carriage are partially disassembled for transport and reassembled for firing on the ground.

9. Characteristics and Capabilities

Some of the characteristics and capabilities of field artillery weapons and tank weapons used in an indirect fire role, are listed in table I in the back of the manual.

Table I. Characteristics and Capabilities of Artillery Weapons
(Located in back of manual)

Section III. AMMUNITION

10. General

A complete round of artillery ammunition contains all of the components necessary to propel the projectile from the weapon and cause it to burst at the desired time and place. The components are the primer, propelling charge, projectile, and fuze. Depending on the manner in which the components are assembled, artillery ammunition is classified as fixed, semifixed, and separate-loading. See TM 9-1300-203 for details on artillery ammunition. See table II for ammunition available for each cannon.

11. Primers

Primers are used to ignite the propelling charge. Percussion primers are ignited by a sharp blow with a firing pin. Electric primers, used only in the breechblock of a weapon, are ignited by sending a small electric current through a resistor imbedded in an explosive. If the primer is not capable of igniting the propellant, an igniter charge is added to the propellant and placed between the primer and the propellant.

12. Propelling Charge

A propelling charge is a low-order explosive, which, when burned, generates great pressure within the chamber and, thereby, furnishes the energy to propel the projectile.

a. Increments. Propelling charges are packaged in cloth bag increments (semifixed or separate-loading ammunition, loose in shell cases (fixed ammunition), or, in the case of the 4.2-inch mortar, in sheetlike bundles attached to a cartridge container. Greater flexibility in projectile range and angle of fall is provided by

varying the muzzle velocity by varying the number of increments to be fired.

b. Positioning Propelling Charge. In separate loading ammunition, the base of the powder bag should be flush against the mushroom head in order to achieve uniform propellant performance.

c. Tie Straps and Wrappings. Loose tie straps or wrappings allows an increase in bag diameter from the original size. A change in bag diameter will change the time of burning for a given propellant and may result in erratic velocity.

13. Projectiles

A projectile is an object that is propelled from a weapon by an explosive propellant charge. All projectiles are of the same general shape in that they have cylindrical bodies and an ogival head.

a. High Explosive (HE) Projectile. High explosive projectiles are hollow projectiles filled with either composition B or TNT. The terminal ballistics and affects of this projectile are discussed in chapter 30.

b. Base Ejection Projectile. Base ejection projectiles are smoke, propaganda, or illuminating. Before reaching the point of impact, the contents of the projectile are ejected from the base of the projectile through the action of the time fuze and expelling charge.

c. Burst-Type Chemical Projectile. Burst-type chemical projectiles include gas projectiles and smoke projectiles. The contents of the projectiles are expelled upon action of a burster projectile charge which runs through the long axis of the projectile.

d. High-Explosive, Antitank (HEAT) Projectile. HEAT projectiles are provided for the 105-mm howitzer for use against armored material. The projectile body is a thin-walled casing which contains a shaped high-explosive charge. The projectile has a ballistic cap of thin steel to provide better ballistic performance during flight.

e. High-Explosive, Plastic (HEP) Projectile. HEP projectiles are used primarily against armored targets. The cartridge has one bag of propellant M1 for its propelling charge. The projectile body is thin-walled casing containing composition A₃ and is internally threaded at the base to receive a BD fuze. When fuze with the M91 or M91A1 BD fuze, the cartridge is designated HEP-T (the BD 91 series fuzes contain an integral tracer). The BD M62A1 has no tracer and when the cartridge is so fuze, it is designated HEP.

14. Fuzes

The proper fuze must be used with the selected projectile to cause the projectile to function at the time and place desired. Fuzes are classified according to the method of functioning as time, impact, or proximity (variable time (VT)).

a. Time fuzes contain a graduated time element in the form of a compressed black powder train or a gear train (as in a clock) that may be set, prior to firing, to a predetermined time. After firing, a time fuze functions as soon as the time set on the fuze has elapsed.

b. Impact fuzes function when they strike a solid object. Impact fuzes are further classified according to the delay of action after impact as superquick, nondelay, and delay.

c. Proximity (VT) fuzes function when they approach any object that will reflect with sufficient strength the signal radiated from the fuze.

d. See table II for fuze interchangeability.

Table II. Ammunition Chart
(Located in back of manual)

Table III. (Rescinded)

CHAPTER 2

FUNDAMENTALS OF FIELD ARTILLERY GUNNERY

Section I. ELEMENTS OF FIRING DATA

15. General

a. The data that are required to lay (point) artillery cannons so that the projectile fired by the cannons will burst at the desired point are called firing data. These data are based on the direction, horizontal distance (range), and vertical interval from the weapons to the target and on the desired pattern of bursts at the target.

b. The principal unit of angular measurement in field artillery is the mil (m). A mil is the angle subtended by an arc which is one-sixty-four-hundredths of the circumference of a circle.

16. Direction

Direction is expressed as an angular measurement from a reference direction. The field artillery normally uses grid north (the direction of the north-south grid lines on a military map) for the reference direction. When pieces are emplaced, they are laid for direction, and the direction in which they are laid is used as a basis for angular shifts to point the piece at the target. The direction to the target may be computed, determined graphically, or estimated.

17. Range

Range is the horizontal distance from the gun to the target and is expressed in meters. Range may be computed, measured graphically, or estimated. The range achieved by a projectile is a function of the charge (muzzle velocity) and the vertical angle (elevation) to which the tube is raised. (For other factors affecting range, see par. 20-23.)

18. Vertical Interval

Vertical interval is the difference in altitude found by algebraically subtracting the altitude

of the battery or observation post from the altitude of the target or point of burst. The vertical interval is computed to the nearest meter from maps, by survey, or by shift from a known point.

19. Distribution

Distribution is the pattern of burst in the target area. Normally, all pieces of a battery fire with the same deflection (parallel sheaf),

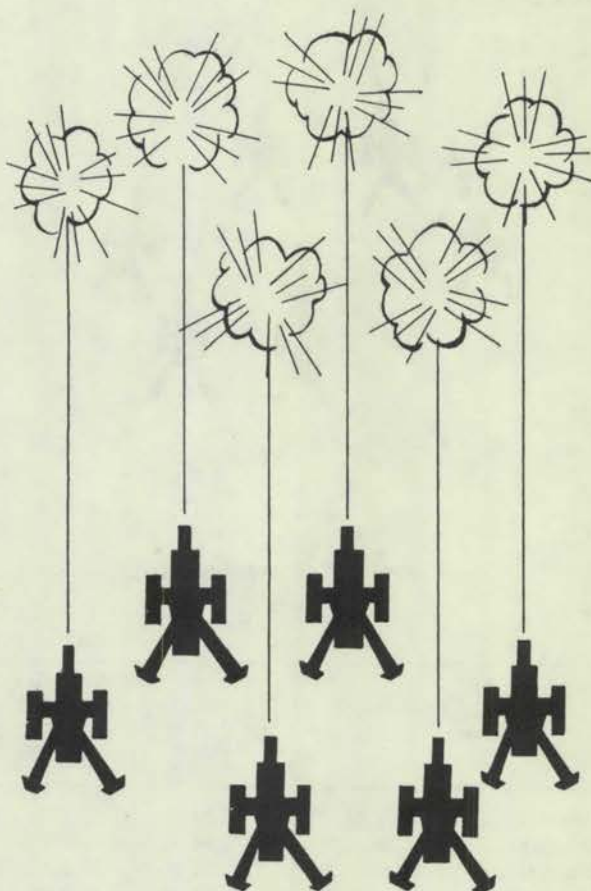


Figure 1. Parallel (normal) sheaf.

fuze setting, and quadrant elevation. However, since targets are of various shapes and sizes, it is sometimes desirable to adjust the pattern of bursts to the shape and size of the target.

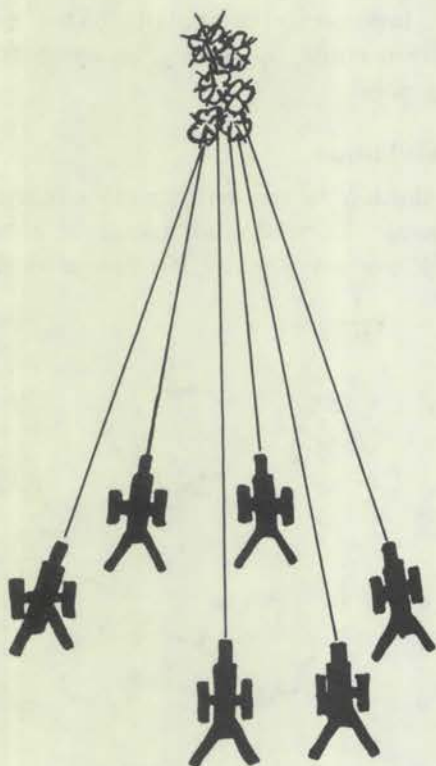


Figure 2. Converged sheaf.

a. In rare cases, individual piece corrections for deflection, fuze setting, and quadrant elevation, are carefully computed and applied to obtain a specific pattern of bursts. These corrections are called "special corrections."

b. In some cases, a rapid computation of deflection difference is made and applied to the pieces to make the distance between flank bursts approximately equal to the width of the target.

c. The term "sheaf" is used to denote the lateral distribution of the bursts of two or more pieces fired together. The width of the sheaf is the lateral distance (perpendicular to the direction of fire) between the centers of the flank bursts. The front covered by any sheaf is the width of the sheaf plus the effective width of one burst. A sheaf may be formed in any one of the following patterns:

- (1) *Parallel (normal) sheaf.* A parallel sheaf is one in which the planes of fire of all pieces are parallel (fig. 1). Regardless of the range, the bursts will be spaced laterally at the same intervals as the pieces.
- (2) *Converged sheaf.* A converged sheaf is one in which the planes of fire intersect at the target (fig. 2). A converged sheaf is obtained by using a deflection difference (para. 71 and 83c).
- (3) *Open sheaf.* An open sheaf is one in which the lateral distance between adjacent bursts is equal to the maximum effective width of burst (table IV and fig. 3).
- (4) *Special sheaf.* A special sheaf is any sheaf other than one of those described in (1) through (3) above.

Table IV. Open Sheaves

Caliber	Width (in meters) of open sheaf			Front (in meters) covered by an open sheaf		
	2-piece battery	4-piece battery	6-piece battery	2-piece battery	4-piece battery	6-piece battery
105-mm	30	90	150	60	120	180*
155-mm	50	150	250	100	200	300
175-mm	95	285	475	190	380	570
8-inch	80	240	---	160	320	---

* For fire planning purposes, a 6-piece 105-mm howitzer battery will normally fire a barrage 200 meters in width.

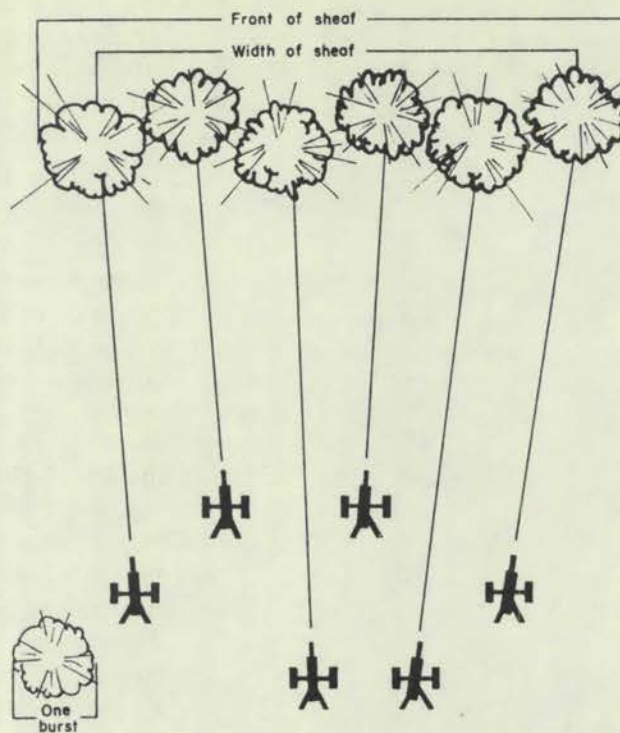


Figure 3. Open sheaf.

Section II. ELEMENTARY BALLISTICS

20. General

Ballistics is the science which deals with the motion of projectiles and the conditions which affect that motion. The branches of ballistics which affect the accuracy of artillery fire are interior ballistics and exterior ballistics.

21. Interior Ballistics

Interior ballistics deals with the factors affecting the motion of the projectile within the tube. These factors are of interest to the artilleryman because they influence the velocity of the projectile as it leaves the tube (muzzle velocity) and, thereby, influence the range achieved by the projectile. Among the factors are—

a. Wear of the Tube. Wearing away of the inner surface of the tube (erosion) is caused by the movement of the gases and residues generated by the burning of the propellant and by the friction between the projectiles and the bore. The resultant enlargement of the bore allows the propelling gases to escape between the projectile and the bore, causing a decrease in muzzle velocity. As the bore is enlarged, the projectile may be rammed further into the tube, causing an increase in the volume of the chamber, a further reduction in pressure, and, therefore, a reduction in muzzle velocity.

b. Ramming. When separate-loading ammunition is used, hard, uniform ramming is required to achieve a uniform chamber volume and thereby to reduce the round-to-round variation in muzzle velocity.

c. Rotating Band. The rotating band must be smooth and free of burrs and scars to permit proper seating of the projectile. If the projectile is improperly seated, gas will escape, muzzle velocity will decrease, and shearing and gouging of lands may result.

d. Propelling Charge. Differences in propelling charge temperature and moisture content will cause variations in rates of burning with resultant variations in muzzle velocity. Variations in the position of the charges in the powder chamber change the speed of burning with a resultant variation in muzzle velocity.

e. Coppering. Firing with higher charges will cause the rotating bands to deposit metal on the lands within the tube (coppering). Light coppering tends to increase muzzle velocity. Excessive coppering causes a decrease in muzzle velocity. With howitzers, excessive coppering can be removed by firing several rounds with minimum charge. High velocity weapons with excessive coppering should be referred to ordnance for removal of the coppering.

f. Weight of Projectile. Projectiles of the same caliber may vary in weight. A heavier-than-standard projectile, all other conditions remaining unchanged, will leave the muzzle with a lower velocity than a projectile of standard weight.

g. Manufacturers' Tolerances. Slight variations from standard in the manufacture of the tube, propellant lots, and primer lots will cause minor variations in the muzzle velocity.

h. Oily Tube. Before firing, oil should be removed from the tube of a cannon. Oil in a tube will cause abnormal variations in muzzle velocity. Projectiles should not be oiled.

Note. For a more detailed treatment of interior ballistics, see chapter 27.

22. Exterior Ballistics

Exterior ballistics deal with the factors which affect the motion of the projectile after it leaves the piece and as it moves along the trajectory. Among the factors are—

a. Drift. Artillery cannons impart a spin to the projectiles in order to provide stability in flight. The spin of United States artillery projectiles, is clockwise when viewed from the rear of the cannon. This spin causes the projectile to assume some of the characteristics of a gyroscope. The action of various forces (gravity, air resistance, etc.) upon a gyro-like projectile causes the projectile to drift to the right.

b. Weight of Projectile. At the same muzzle velocity, a heavier projectile will travel farther than a lighter projectile of the same size and shape. (As an analogy, a man can throw a golf ball farther than he can throw a pingpong ball.)

c. Air Density. An increase in air density increases the resistance to the motion of the projectile and, therefore, decreases the range.

d. Air Temperature. Air temperature variations change the velocity of sound and, therefore, the relationship between the velocity of the projectile and the velocity of sound (Mach number). At low muzzle velocities (low charges), air temperature has little effect on range, but, at muzzle velocities close to or greater than the speed of sound, variations in air temperature have an appreciable effect on range.

e. Wind. Wind will modify the normal trajectory of a projectile. For example, a headwind decreases the range; wind from the right moves the projectile to the left; and the effect of an oblique wind is divided into components parallel to, and perpendicular to, the direction of fire.

f. Muzzle Velocity. A variation in muzzle velocity causes a variation in range.

g. Rotation of Earth. Although the rotation of the earth is a natural phenomenon, it is treated as a nonstandard condition for simplicity in the construction of firing tables. The magnitude and direction of projectile displacement from the target owing to rotational effects are functions of azimuth of fire, time of flight, projectile velocity, and relative position of piece and target with respect to the Equator. These effects have been combined in convenient tabular form in firing tables.

h. Shell Surface Finish. A rough surface on the projectile or fuze will increase air resistance, thereby, decreasing range.

i. Ballistic Coefficient. The ballistic coefficient of a particular projectile is the measure of the ability of that projectile to overcome air

resistance. The ballistic coefficient varies depending on the form, finish, diameter, and mass of the projectile.

j. Ballistic Coefficient Change (BCC). The ballistic coefficient change is the difference in efficiency between any given projectile lot and the specific projectile lot used for construction of the firing tables. The ballistic coefficient change is expressed as a percentage change in air density.

k. Drag. Air resistance affects the flight of the projectile both in range and deflection. That component of air resistance which resists the forward motion (range) of the projectile is called drag.

23. Corrections

In paragraph 21 and 22, certain factors were discussed which affected the motion of a projectile. Certain conditions are accepted as standard. When a variation from the standard condition can be measured, corrections can be made to compensate for the variation. Among the conditions for which corrections may be determined are—

- a. Drift.
- b. Propellant (powder) temperature.
- c. Weight of projectiles.
- d. Air density.
- e. Air temperature.
- f. Differences in muzzle velocity.
- g. Horizontal wind.
- h. Effects of rotation of the earth.
- i. Barrel curvature.
- j. Ballistic coefficient change.

Section III. TRAJECTORY

24. General

The trajectory is the curve traced by the center of gravity of the projectile in its flight from the muzzle of the weapon to the point of impact or burst.

25. Elements of the Trajectory

The elements of a trajectory are classified into three groups—intrinsic elements, initial elements, and terminal elements. Intrinsic ele-

ments are those which are characteristic of a trajectory by its very nature. Initial elements are those which are characteristic at the origin of the trajectory. Terminal elements are those which are characteristic at the point of impact (point of burst).

26. Intrinsic Elements

(fig. 4)

a. Origin. The location of the center of gravity of the projectile when it leaves the

muzzle of the piece is designated the origin of the trajectory. However, because the magnitude and the direction of jump and therefore line of departure (para. 27b and c) cannot be predetermined, the term origin for the remaining definitions designates the center of the muzzle when the piece is laid.

b. *Ascending Branch.* The ascending branch is that portion of the trajectory traced while the projectile is rising from the origin.

c. *Descending Branch.* The descending branch is that portion of the trajectory traced while the projectile is falling.

d. *Summit.* The summit is the highest point of the trajectory. It is the end of the ascending branch and the beginning of the descending branch.

e. *Maximum Ordinate.* The maximum ordinate is the difference in altitude between the origin and the summit. Firing tables list the maximum ordinate for each 500 meters range.

f. *Level Point.* The level point is the point on the descending branch of the trajectory which is at the same altitude as the origin.

g. *Base of Trajectory.* The base of the trajectory is the straight line from the origin to the level point.

27. Initial Elements

(fig. 5)

a. *Line of Elevation.* When the piece is laid the line of elevation is the axis of the tube extended.

b. *Line of Departure.* The line of departure is a line tangent to the trajectory at the instant the projectile leaves the tube.

c. *Jump.* Jump is the displacement of the line of departure from the line of elevation that exists at the instant the projectile leaves the tube. Jump is caused by the shock of firing during the interval from the ignition of the propelling charge to the departure of the projectile from the tube.

d. *Angle of Site.* The angle of site is the smaller angle in the vertical plane from the base of the trajectory to the straight line joining the origin and the target. The angle of site is plus when the target is above the base of the trajectory and minus when the target is below the base of the trajectory. The angle of site compensates for the vertical interval (para. 18).

e. *Complementary Angle of Site.* The complementary angle of site is an angle which is algebraically added to the angle of site to compensate for the nonrigidity of the trajectory. The trajectory may be rotated vertically about the origin an amount equal to small angles of site without significantly affecting its shape. When large angles of site or the longer ranges for any one charge are involved, significant error is introduced because the shape of the trajectory changes. The value and sign of the complementary angle of site is dependent upon the angle of site, the range, the shape of the trajectory (low or high angle fire), and the muzzle velocity. The complementary angle of

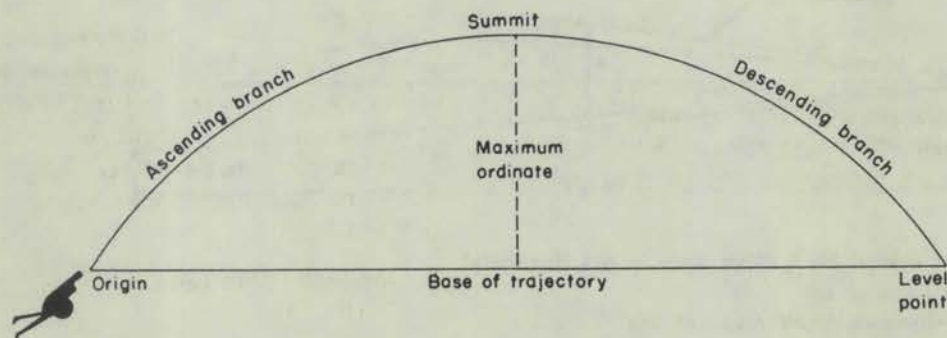
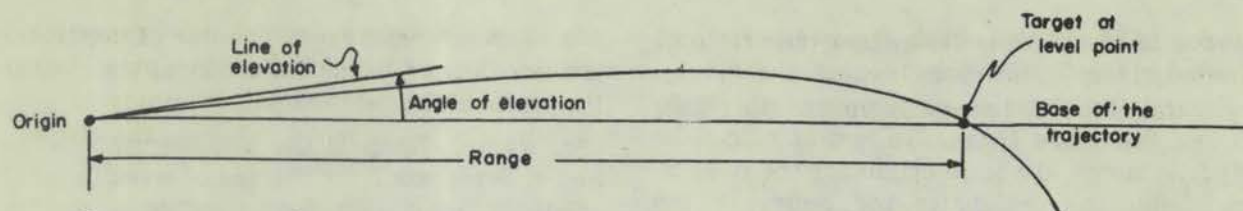
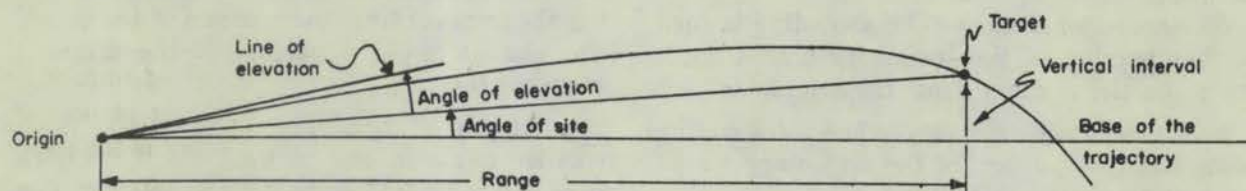


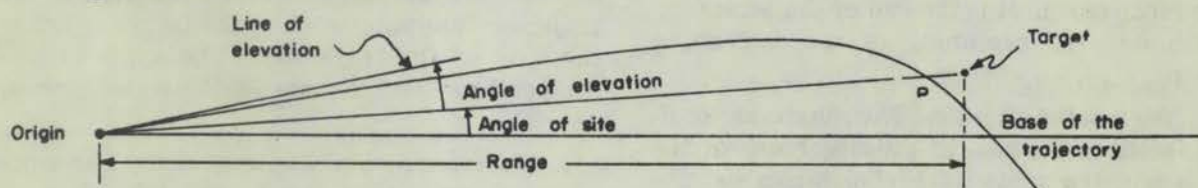
Figure 4. Intrinsic elements of a trajectory.



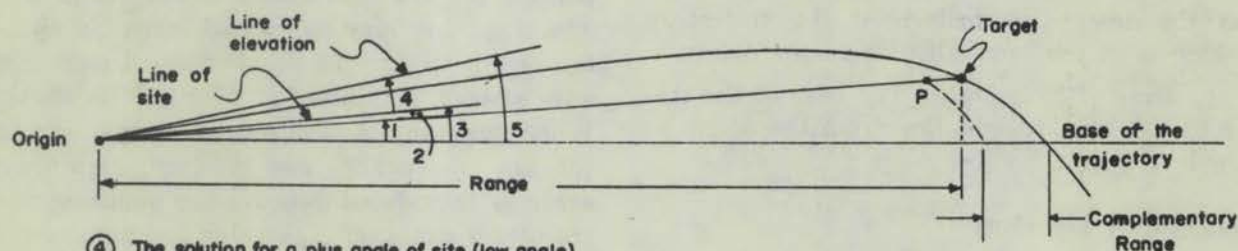
① Trajectory with zero angle of site



② Hypothetical (rigid) trajectory

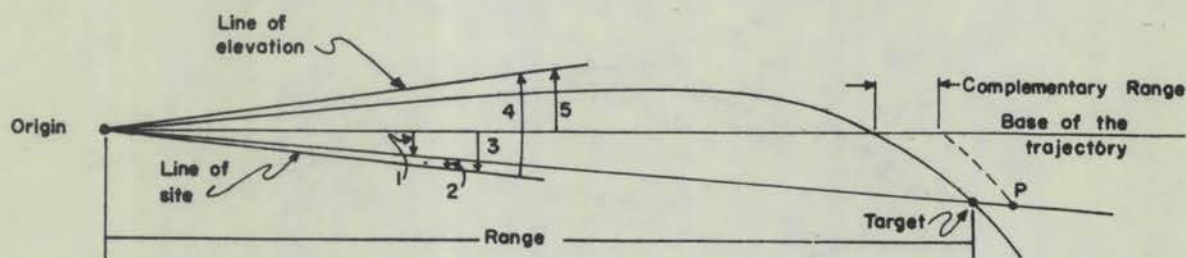


③ Actual (nonrigid) trajectory



④ The solution for a plus angle of site (low angle)

- 1: Angle of site
- 2: Complementary angle of site
- 3: Site
- 4: Angle of elevation
- 5: Quadrant elevation



⑤ The solution for a minus angle of site (low angle)

- 1: Angle of site
- 2: Complementary angle of site
- 3: Site
- 4: Angle of elevation
- 5: Quadrant elevation

Figure 5. Initial elements of the trajectory.

site for ± 1 mil angle of site (comp site factor) is listed in the firing tables.

f. Site. Site is the algebraic sum of the angle of site plus the complementary angle of site.

g. Complementary Range. Complementary range is the range correction equivalent to the complementary angle of site. Complementary range can be determined from the firing tables.

h. Line of Site. The line of site is the straight line from the origin which together with the base of the trajectory represents the angle called site.

i. Angle of Elevation. The angle of elevation is the smaller angle at the origin in a vertical plane from the line of site to the line of elevation.

j. Quadrant Elevation. The quadrant elevation is the smaller angle at the origin in a vertical plane from the base of the trajectory to the line of elevation. Quadrant elevation is the algebraic sum of site plus the angle of elevation. Quadrant elevation can also be computed by algebraically adding the angle of site to the angle of elevation corresponding to range plus complementary range. The two methods of computing quadrant elevation, one using the complementary angle of site and the other using complementary range, both compensate for the nonrigidity of the trajectory. Complementary

angle of site or complementary range may be used when the firing data is computed using the firing table; complementary angle of site is used when site is computed using the graphical site table.

28. Terminal Elements

(fig. 6)

a. Point of Impact. The point of impact is the point where the projectile first strikes in the target area. (The point of burst is the point at which a projectile bursts in the air.)

b. Line of Fall. The line of fall is the line tangent to the trajectory at the level point.

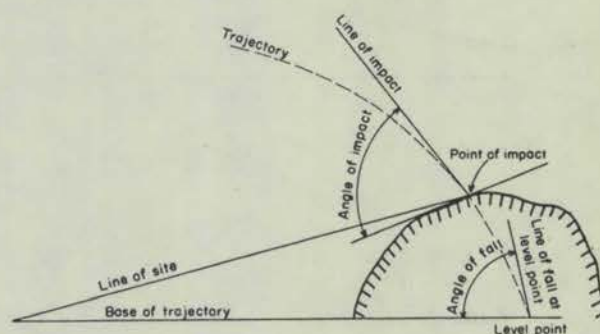


Figure 6. Terminal elements of the trajectory.

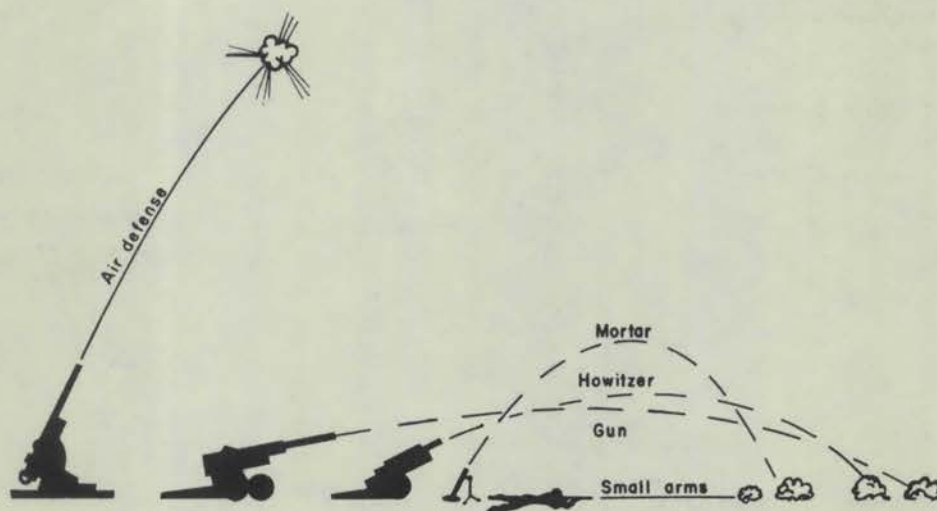


Figure 7. Typical trajectories in air.

c. *Angle of Fall.* The angle of fall is the vertical angle, at the level point, between the line of fall and the base of the trajectory.

d. *Line of Impact.* The line of impact is a line tangent to the trajectory at the point of impact.

e. *Angle of Impact.* The angle of impact is the acute angle, at the point of impact, between the line of impact and a plane tangent to the surface at the point of impact. This term should not be confused with the term "angle of fall."

29. Form of Trajectory

a. In a vacuum, the form of the trajectory would be determined entirely by the elevation of the tube, the muzzle velocity, and gravity. The form would be parabolic with the angle of

fall equal to the angle of elevation. The summit would be at a point halfway between the origin and the level point.

b. Air resistance retards the projectile from the instant it leaves the piece. This makes the trajectory (fig. 7) a more complex curve than it would be in a vacuum; the angle of fall is greater than the angle of elevation; the summit is closer to the level point than to the origin; and the range is greatly reduced. Air resistance is approximately proportional to the square of the velocity and varies with the shape of the projectile. Retardation (the effect of air resistance on a projectile) depends on the ratio of air resistance to mass of projectile. In general, retardation is less for large projectiles than for smaller ones of the same shape.

Section IV. DISPERSION

30. General

a. If a number of rounds of the same caliber and same lot of ammunition are fired from the same weapon with the same settings in quadrant elevation and deflection, the rounds will not all fall at a single point but will be scattered in a pattern of bursts. In discussions of artillery fire, this natural phenomenon of chance is called dispersion. The array of the bursts on the ground is the dispersion pattern.

b. The points of impact of the projectiles will be scattered both laterally (deflection) and in depth (range). Dispersion is caused by inherent errors and must not be confused with variations in point of impact caused by mistakes or constant errors. Dispersion is the result of minor variations of many elements from round to round. Mistakes and constant errors can be eliminated or compensated for. Those inherent errors which are beyond control and cause dispersion are caused in part by—

- (1) *Conditions in the bore.* Muzzle velocity is affected by minor variations in weight, moisture content, and temperature of the propelling charge; variations in the arrangement of the powder grains; difference in the ignition of the charge; differences in the weight of the projectile and in the form of the rotating band; variation in ramming; and variations in the temperature of the bore from round to round. Variation in the bourrelet and rotating band may cause inaccurate centering of the projectile; hence, inaccurate flight.
- (2) *Conditions in the carriage.* Direction and elevation are affected by play (looseness) in the mechanisms of the carriage, physical limitations on precision in setting scales, and nonuniform reaction to firing stresses.
- (3) *Conditions during flight.* Air resistance is affected by differences in weight, velocity, and form of projectile and by changes in wind, density, and temperature of the air from round to round.

31. Center of Impact

For any large number of rounds fired, it is possible to draw a diagram showing a line perpendicular to the line of fire that will divide the points of impact into two equal groups. Half of the rounds considered will be beyond the line, or *over* when considered from the weapon; half will be inside the line, or *short* when considered from the weapon. For this same group of rounds there will also be a line parallel to the line of fire which will divide the rounds equally with half of the rounds falling to the right of the line and half to the left. The first line, perpendicular to the line of fire, represents the mean range; the second line, parallel to the line of fire, represents the mean deflection. The intersection of the two lines is the center of impact (fig. 8).

32. Probable Error

Consider for a moment only the rounds that have fallen over (or short) of the center of impact. There is some point along the line of fire, beyond the center of impact, at which a second line perpendicular to the line of fire can be drawn, to divide the overs into two equal parts (line AA in fig. 9). All the rounds beyond the center of impact manifest an error in range—they are all *over*. Some of the rounds falling *over* are more in error than others. If the distance from the center of impact to line AA is a measure of error, it is clear that half the rounds over have a greater error; and half the rounds over have a lesser error. The distance from the center of impact to line AA thus becomes a convenient unit of measure. This distance is called one probable error. The most concise definition of a probable error is that it is the error which is exceeded as often as it is not exceeded.

33. Dispersion Pattern

The distribution of rounds in a normal burst pattern will be the same number of rounds short of the center of impact as the number of rounds over the center of impact. The probable error will be the same in both cases.

a. It is a coincidence of nature that for any normal distribution (such as artillery fire) a

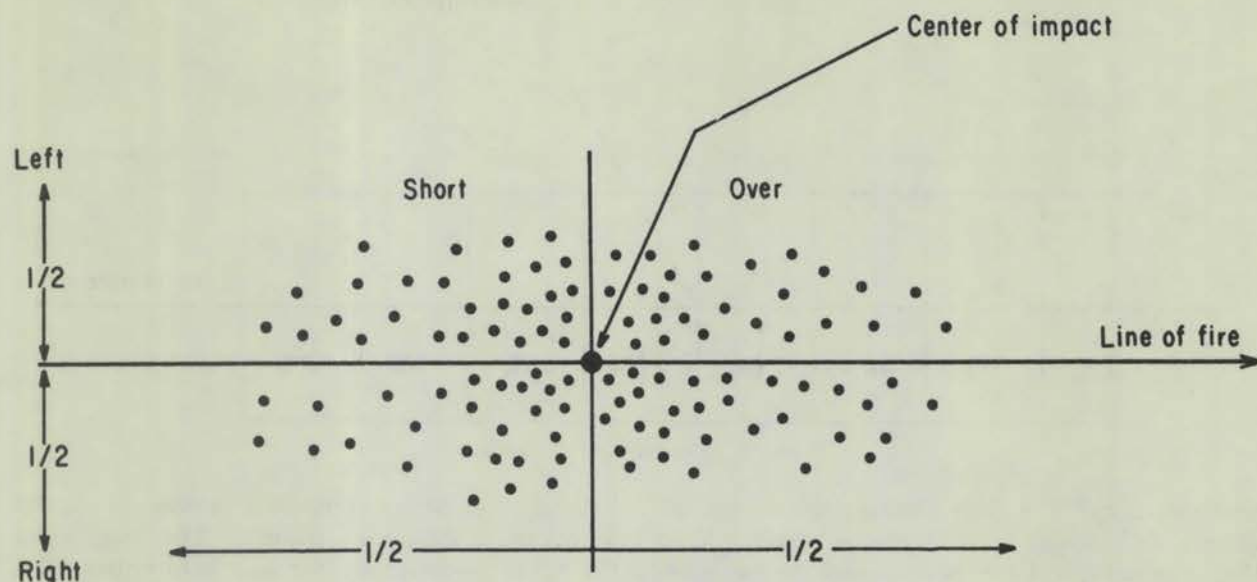


Figure 8. Dispersion.

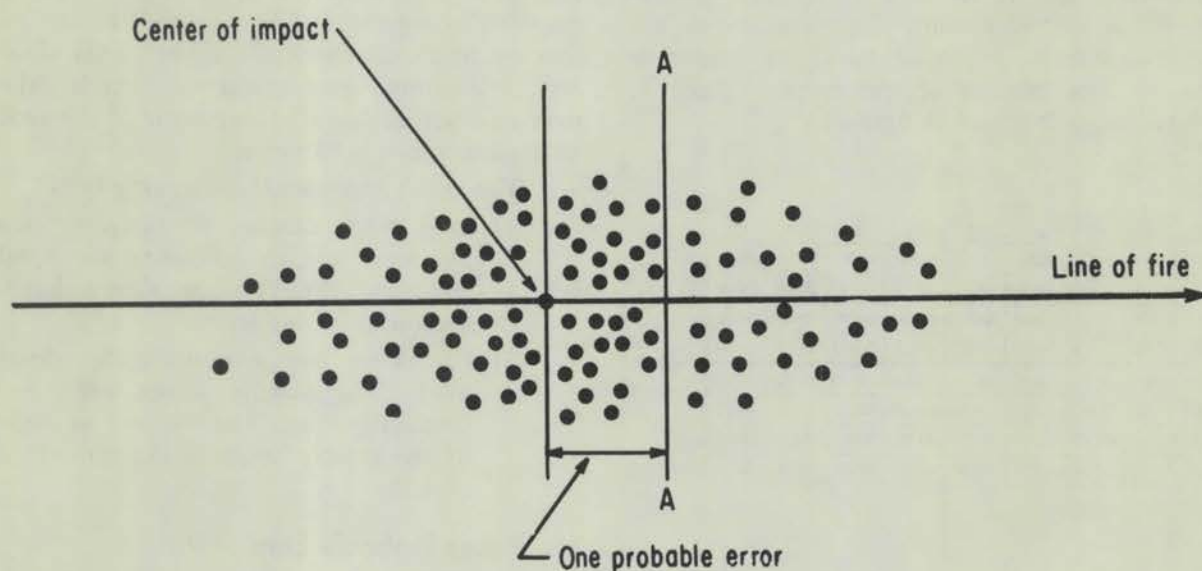


Figure 9. Range probable error.

distance of four probable errors on either side of the center of impact will include virtually all of the events (bursts). This is not precisely true, since a very small fraction of the rounds (approximately 7 out of 1,000) will fall outside four probable errors; but it is true for all practical purposes.

b. The total pattern of a large number of bursts is roughly elliptical (fig. 9). However, using the fact that four probable errors (in range and in deflection) encompass virtually all

rounds, a rectangle is normally drawn to include the full distribution of the rounds. This rectangle is the 100-percent rectangle (fig. 10).

34. Dispersion Scale

If, using one probable error as the unit of measurement, the dispersion rectangle is divided evenly into eight zones in range, the percentage of rounds falling in each zone will be as indicated in figure 10. By definition of probable error, the 50 percent of rounds nearest

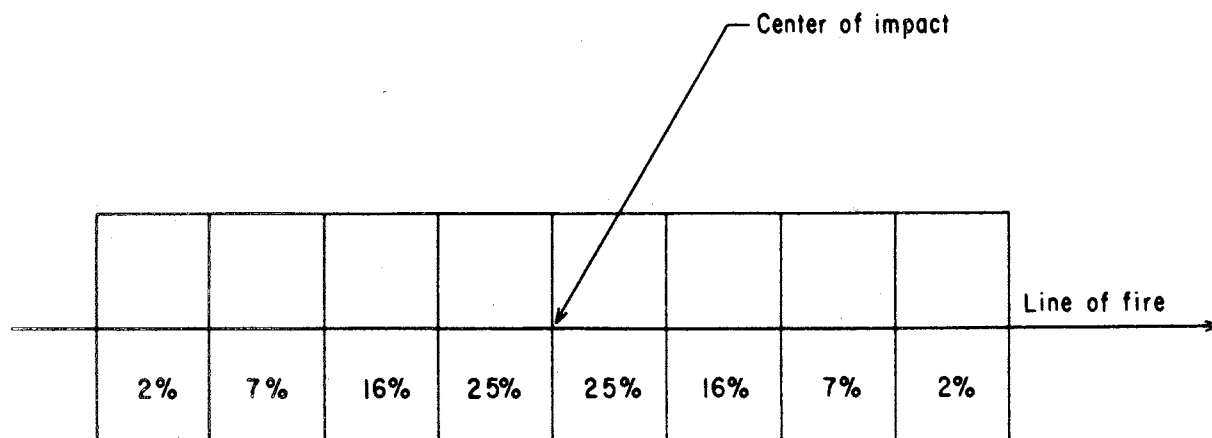


Figure 10. The 100-percent rectangle.

the mean range line (line through the center of impact) fall within one probable error. The other percentages have been found to be true by experiment. Again, what is true in range will be true also in deflection. If range dispersion zones and deflection dispersion zones are both considered, a set of small rectangles is created. The percent of the rounds falling in each rectangle is shown in figure 11.

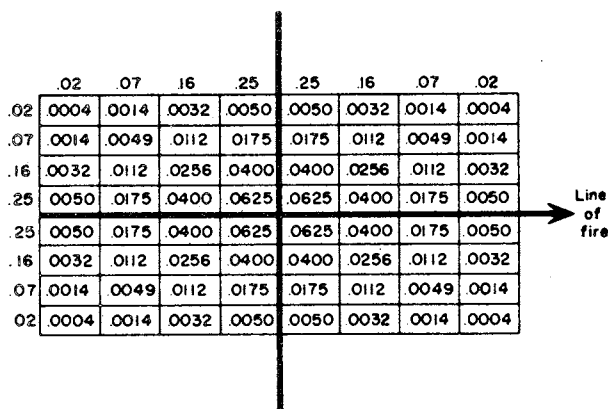


Figure 11. Dispersion rectangle.

35. Normal Probability Curve

a. The dispersion of artillery shells follows the laws of probabilities and normal distribution. The pattern of bursts on the ground can be graphed with a normal probability curve, a common method of representing the probability of the occurrence of an error of any given magnitude in a series of samples.

b. Distances of points on the horizontal (base) line (fig. 12) measured to the right and

left of the center represent errors in excess (over) or in deficiency (short). The area under the curve enclosed by vertical lines cutting the base line and the curve represents the probability of the occurrence of an error within the magnitudes represented by the ends of the base line segment considered. In figure 12 the shaded area represents the number of rounds falling over and within one probable error of the center of impact, which is 25 percent.

c. The curve expresses the following facts:

- (1) In a large number of samples, errors in excess and in deficiency are equally frequent (probable) as shown by the symmetry of the curve.
- (2) The errors are not uniformly distributed. The smaller errors occur more frequently than the larger, as shown by the greater height of the curve in the middle.

36. Range Probable Error (PE_r)

The approximate value of the range probable error is shown in the firing tables and can be taken as an index of the precision of the piece. Firing table values for probable errors are based on the firing of carefully selected ammunition under controlled conditions. The actual round-to-round probable error experienced in the field will normally be larger.

37. Fork

Fork is the term used to express the change in elevation in mils necessary to move the center

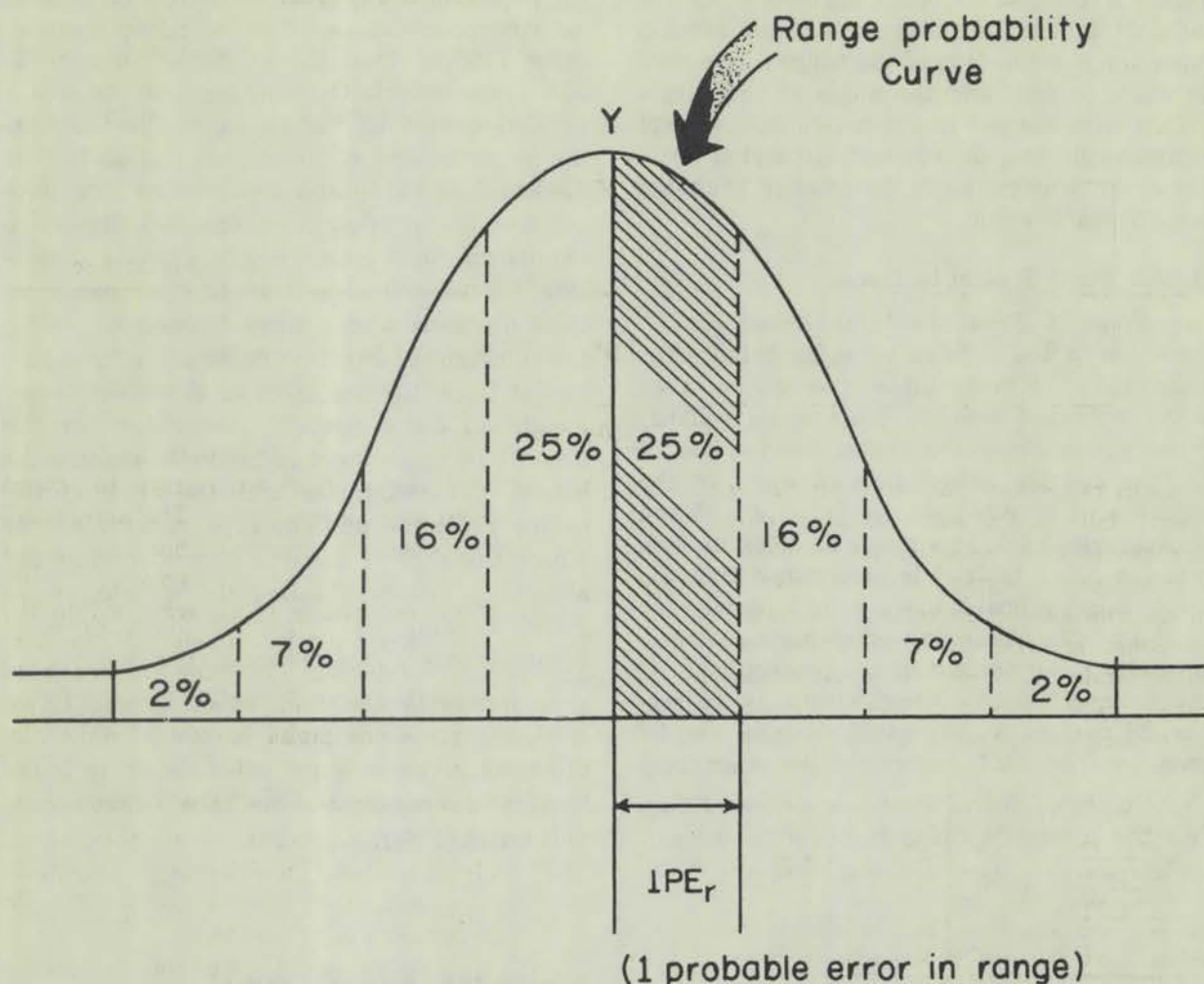


Figure 12. Areas under the normal probability curve.

of impact four range probable errors. The value of the fork is given in the firing tables. For example, in firing a 155-mm howitzer at a range of 6,000 meters, charge 5, from the tabular firing tables it is determined that the fork is 7 mils or, converted to meters, 105 meters.

38. Deflection Probable Error (PE_d)

The value of the deflection probable error is given in the firing tables. For cannons, the deflection probable error is considerably smaller than the range probable error. For example, in firing a 155-mm howitzer, charge 5, at a range of 5,000 meters, from the firing table it is determined that the deflection probable error is

1 meter. In other words, 50 percent of the projectiles fired will hit within 1 meter, 82 percent will hit within 2 meters, and 96 percent will hit within 3 meters of the mean deflection.

39. Vertical Probable Error (PE_h)

The range probable error given in the firing tables is based on firing on a horizontal plane. If the target is a vertical surface (or even a steep incline), the probable error for range will be different. When the target is truly vertical, the probable error against the target surface is equal to the tangent of the angle of fall times the range probable error (fig. 13). Precise computation of the size of the probable error

against a vertical or steep surface is seldom made. It suffices to recognize that the vertical dispersion is a function of the range dispersion, the angle of fall, and the angle of the target surface with respect to the horizontal. Except in high-angle fire, the vertical dispersion probable error will normally be smaller than the range probable error.

40. Air Burst Probable Errors

a. *Time to Burst Probable Error (PE_T)*. The value of the time to burst probable error is shown in the firing tables and can be taken as the weighted average (root mean square) of the precision of the timing mechanism of the fuze and the actual time of flight of the projectile. For example, in firing a 155-mm howitzer, charge 5, at a range of 5,000 meters, from the firing table it is determined that the time to burst probable error is 0.15 seconds for the M520 fuze. As in any other normal dispersion pattern, 50 percent of the projectiles fired with fuze, M520 will burst within ± 0.15 seconds, 82 percent within ± 0.30 seconds, and 96 percent within ± 0.45 seconds of the mean time.

b. *Height of Burst Probable Error (PE_H)*. With the projectile fuzed to burst in the air,

the height of burst probable error is the vertical component of one time to burst probable error (PE_T). Thus the height of burst probable error reflects the combined effects of dispersion caused by variations in the functioning of fuzes and of dispersion due to factors discussed in paragraph 30b. Except for some complexity introduced by the two dispersion phenomena interacting, height of burst dispersion follows the same laws of distribution as those discussed under range dispersion. Values of the height of burst probable error for a particular time fuze are given in the firing tables. Height of burst probable error for variable time (VT) fuze cannot be predicted because the height of burst varies with the angle of fall of the projectile and the type of terrain over which the shell is passing. By observing and analyzing results obtained from firing on a given terrain, the height of burst probable error for fuze VT can be estimated.

c. *Range to Burst Probable Error (PE_R)*. With the projectile fuzed to burst in the air, the total range to burst probable error is the horizontal component of one time to burst probable error (PE_T).

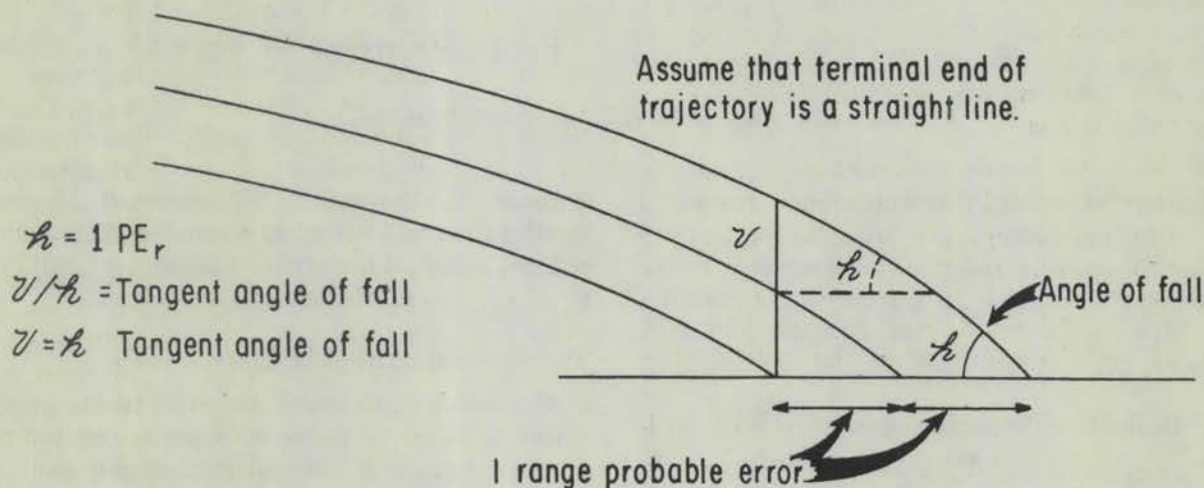


Figure 13. Vertical dispersion.

PART TWO

FIRING BATTERY

CHAPTER 3

FIRING BATTERY, GENERAL

41. Introduction

The firing battery is that component of the gunnery team that executes the fire commands generated at the fire direction center. The firing battery consists of the firing battery headquarters, the howitzer (gun) sections, and, in some units, an ammunition section. Battery fire direction personnel are assigned to the firing battery headquarters. Fire direction at the battery level is accomplished at the battery fire direction center. Fire direction procedures are discussed in part four.

42. Map and Azimuth Terms

(fig. 14)

a. Grid Line. A grid line is a line extending north and south, or east and west, on a map, photomap, or grid sheet. Grid lines are parallel and perpendicular to the central meridian of the grid zone in question. The parallel lines are, normally, 1,000 meters apart and are used to measure coordinates.

b. Magnetic North. Magnetic north is the direction to the North Magnetic Pole.

c. True North. True north is the direction to the geographic North Pole.

d. Grid North. Grid north is the north direction of the vertical grid lines on a military map, photomap, or grid sheet.

e. Azimuth. Azimuth is a direction expressed as a horizontal clockwise angle measured from north. This angle may be a—

- (1) *Magnetic azimuth*, measured from magnetic north.
- (2) *True azimuth*, measured from true north.
- (3) *Grid azimuth*, measured from grid

north. (Grid azimuth is the azimuth normally employed in the field artillery. The artilleryman uses the term "azimuth" to mean "grid azimuth." The command to the executive officer to indicate the grid azimuth of the direction of fire is AZIMUTH (so much).)

f. Back-Azimuth. A back-azimuth is the reverse direction of an azimuth. The back-azimuth is equal to the azimuth plus or minus 3,200 mils, whichever gives a result between 0 to 6,400 mils. The azimuth of line AB (fig. 15) is 500 mils. The back-azimuth of line AB is 3,700 mils (500 plus 3,200). The azimuth of line CD is 3,700 mils, and the back azimuth is 500 mils (3,700 minus 3,200).

g. Declination Constant. Declination constant (fig. 14) is the horizontal, clockwise angle from grid north to magnetic north; in other words, the grid azimuth of magnetic north. This constant is recorded for all instruments equipped with a magnetic needle. The constant for any one instrument will vary in different localities; the constants of different instruments in the same locality will vary also.

h. Magnetic Declination. Magnetic declination (fig. 14) is the angle between true north and magnetic north. This angle is indicated in the marginal data of maps as east or west of true north. Since the magnetic declination varies slightly from year to year, a correction factor (the annual magnetic change) also is shown in the marginal data of military maps.

i. Grid Declination. Grid declination (fig. 14) is the angle between true north and grid north. Grid declination is indicated in the marginal data of maps as east or west of true north.

43. Artillery Firing Battery Terms

a. Aiming point. An aiming point is a clearly defined point that is used as a reference in laying an artillery piece for direction. There are two general types of aiming points—distant aiming points and aiming posts.

(1) *Distant aiming point.* A distant aiming point is one at sufficient distance (at least 2,000 meters) from the position area that normal displacement of the panoramic telescope due to firing and traverse will not cause an error in direction of more than one-half mil. An advantage of using a distant aiming point is that it may be used immediately upon occupation of position. Disadvantages of using a distant aiming point are that it may be obscured by darkness, dust, fog, or smoke; illumination is not practical; and pieces will not be laid parallel when a common deflection for a distance aiming point is used.

(2) *Aiming posts.* Two aiming posts (striped rods) are commonly used as the aiming point for each piece. The aiming posts are placed so that the two aiming posts and the panoramic telescope form a straight line and so

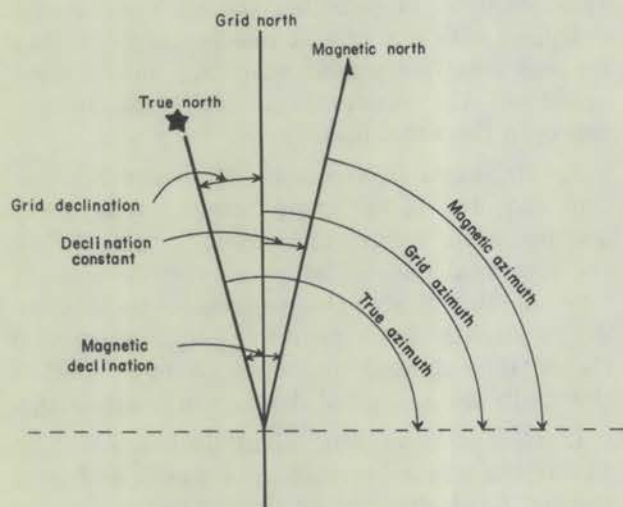


Figure 14. Map and azimuth terms.

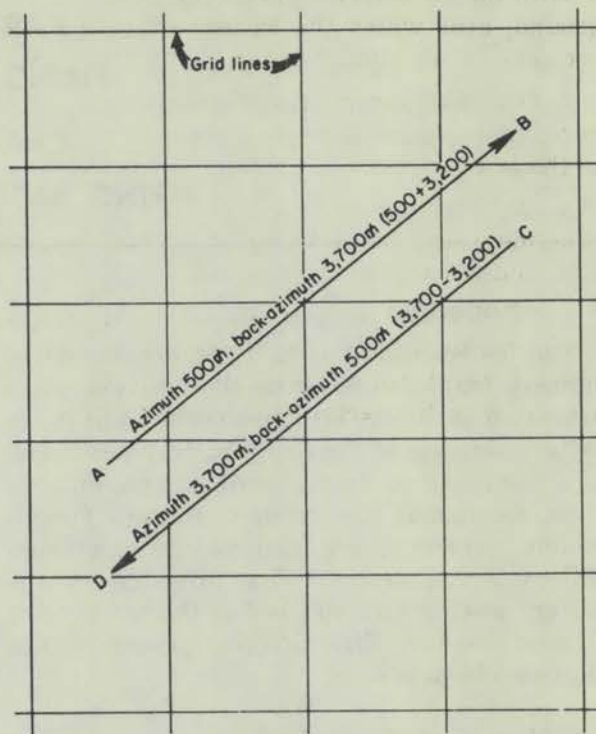


Figure 15. Back-azimuth.

that the near aiming post is halfway between the panoramic telescope and the far aiming post.

b. Battery Center. The battery center is a point materialized on the ground at the approximate geometric center of the battery—the chart location of the battery.

c. Base Piece. The base piece is the piece with the shooting strength closest to the average shooting strength of the battery. It is normally placed near the battery center and used for registrations.

d. Orienting Line. An orienting line is a line of known direction materialized on the ground near the firing battery to serve as a basis for laying for direction. The azimuth of the orienting line is stated as the direction from the orienting station to a designated end of the orienting line. The end of the orienting line may be marked by any sharply defined point, such as a steeple, flagpole, or stake.

e. Orienting Station. An orienting station is a point on the orienting line established on the ground, over which the battery executive officer sets up an aiming circle to lay the pieces.

f. Orienting Angle. An orienting angle is the horizontal, clockwise angle from the line of fire to the orienting line.

g. Reference Point. A reference point is a prominent and easily located point on the terrain and is used for orientation.

h. Deflection. Deflection is the horizontal, clockwise angle from the direction of fire to the line of sight to a designated aiming point (post), with the vertex at the instrument.

i. Refer. To refer is to measure the deflection to a given aiming point without moving the 0-3200 line of the instrument. The command REFER means to measure and to report the deflection. If it is desired to record this deflection, the command is RECORD REFERRED DEFLECTION.

j. Indirect Laying. When indirect laying procedure is used, the piece is laid for direction by setting a given deflection on the sight and traversing the tube until the line of sight of the panoramic telescope is on the aiming point and the appropriate bubbles are leveled. The piece

is laid for elevation by setting the quadrant elevation on the range quadrant or gunner's quadrant and elevating or depressing the tube until the appropriate bubble is level.

k. *Direct Laying.* When direct laying procedure is used, the piece is laid by sighting on the target.

44. Aiming Circle

a. The aiming circle is an instrument for measuring horizontal and vertical angles. It is the instrument usually used to lay the battery. The head of the instrument has two motions called the lower motion and the upper motion. On the lower motion, which may be locked in any desired position, there is an azimuth scale, (fig. 16) graduated every 100 mils and numbered every 200 mils. The scale is numbered from 0 to 62 (6,200), and the upper half of the scale, numbered 32 to 62 (3,200 to 6,200), has a second set of numbers, 0 to 30 (0 to 3,000). The upper motion has an index (for the azimuth scale on lower motion), an azimuth micrometer (graduated in mils from 0 to 100), a compass, a reticle for centering the compass needle, and a telescope. The reticle for centering the needle

is located directly below the axis of the telescope. When the compass needle is centered in the reticle, the line of sight of the telescope is in the direction in which the needle is pointing. When the upper motion is moved with respect to the lower motion, the horizontal clockwise angle from the 0-3200 line of the lower motion to the line of sight of the telescope can be determined by combining the values read opposite the appropriate indexes on the azimuth scale and the azimuth micrometer.

b. When the compass of the aiming circle is being used, all objects (helmets, small arms, etc.) which may attract the needle must be kept away from the instrument. The aiming circle should be set up no closer to the following objects than the distances listed.

	Meters
High-tension powerlines	150
Railroad track or very heavy artillery pieces	75
Medium and heavy artillery pieces	60
Light artillery pieces, telegraph wire, or vehicles	40
Barbed wire and small metal objects	10

45. Panoramic Telescope

The panoramic telescope (sometimes called the sight) is mounted on the piece and measures horizontal, clockwise angles. Some panoramic telescopes have a main scale divided into 2 halves each graduated in 100-mil increments from 0 to 3,200 mils. Other panoramic telescopes have main scales numbered from 0 to 6,400 mils in 100-mil increments. All panoramic telescopes have a micrometer scale graduated in mils, from 0 to 100 mils. When a panoramic telescope is properly mounted and all scales are set at zero, the line of sight of the telescope is parallel to the direction in which the tube of the weapon is pointing. The reading on the scales of a panoramic telescope (unless the scales have been slipped) is the value of the horizontal angle measured from the direction in which the tube is pointing to the line of sight of the telescope (fig. 17).

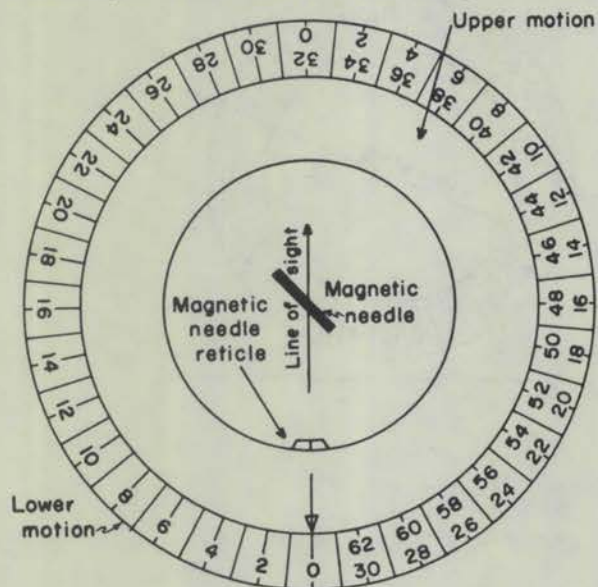


Figure 16. Schematic diagram of aiming circle.

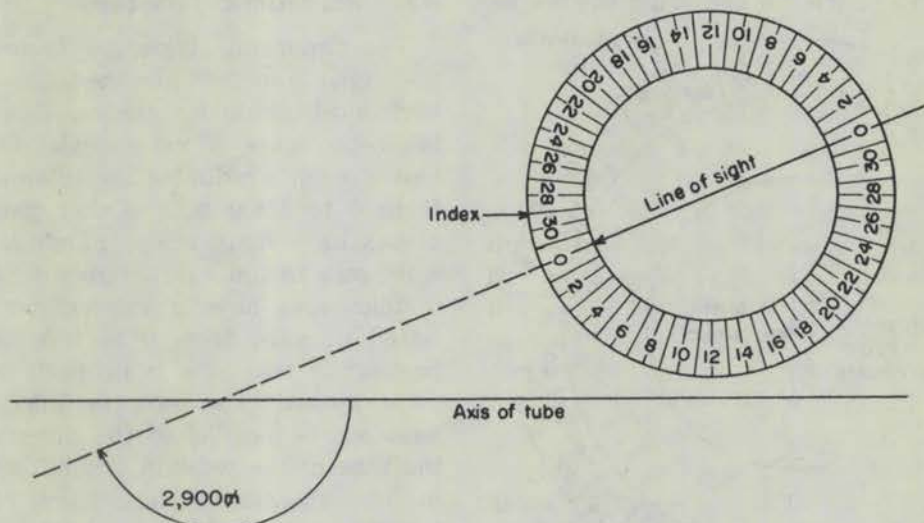
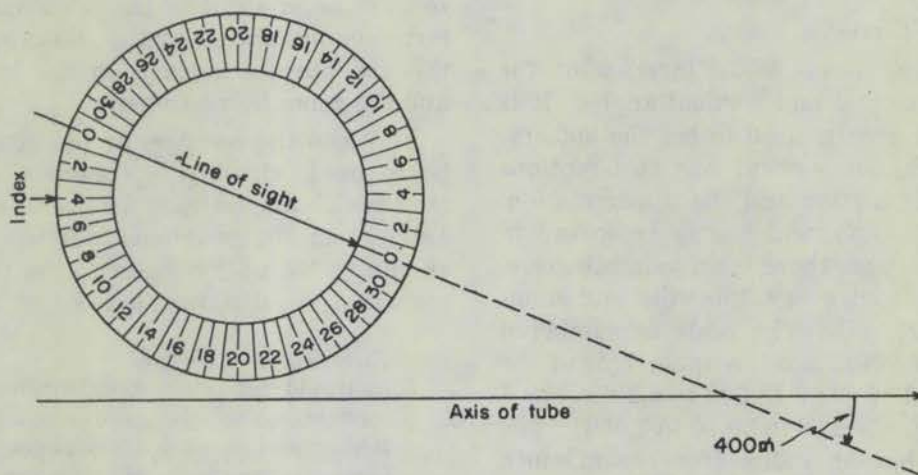


Figure 17. Clockwise angle from axis of tube to line of sight.

CHAPTER 4

FIRING BATTERY PROCEDURES

Section I. LAYING THE BATTERY

46. General

a. When a battery occupies a position, the tubes of the pieces must be pointed in a known direction. The known direction should be the direction toward the center of the assigned zone of fire. The direction in which to lay the battery may be furnished to the battery executive officer, or he may estimate the direction based on his knowledge of the situation.

b. Normally, the battery is laid by following two steps:

- (1) Establish the 0-3200 line of the aiming circle parallel to the direction of fire.
- (2) Lay the howitzer (gun) tubes parallel to the 0-3200 line of the aiming circle (reciprocal laying).

c. In rare cases, it may be necessary or desirable to lay the battery without using an aiming circle (par. 52).

47. Orienting the Aiming Circle

a. *General.* There are several methods that can be used to orient the 0-3200 line of the aiming circle in the direction of fire, but the three methods to be described in this paragraph (azimuth, orienting angle, and aiming point and deflection) are the ones used most often. All three methods are similar in that a deflection (the horizontal angle from direction of fire to aiming point) is determined and set on the aiming circle, and the lower motion of the aiming circle is then used to sight on an aiming point.

b. *Orienting by Grid Azimuth.* In orienting by grid azimuth, magnetic north is used as the aiming point. To orient the 0-3200 line of the aiming circle on a grid azimuth, it is necessary to determine the deflection from that azimuth to magnetic north, to set that deflection on the aiming circle with the upper motion, and to sight on magnetic north by centering (with the lower motion) the magnetic needle in the magnifier. The deflection to set on the aiming circle

is computed by subtracting the grid azimuth from the declination constant of the instrument (adding 6,400, if necessary).

Example: The executive receives the command LAY ON AZIMUTH 5250. The declination constant of the aiming circle is 200 mils.

Solution:

Declination constant	200 mils
	+ 6,400
	6,600 mils
Minus the grid azimuth	- 5,250 mils
	1,350 mils
Deflection to set on the aiming circle	

After setting up the aiming circle at a point away from all magnetic attractions and so that it is visible to all pieces, 1,350 is set on the aiming circle with the upper motion. Using the lower motion, the magnetic needle is centered without disturbing the setting of 1,350. The 0-3200 line of the aiming circle is now pointed on azimuth 5,250 (fig. 18).

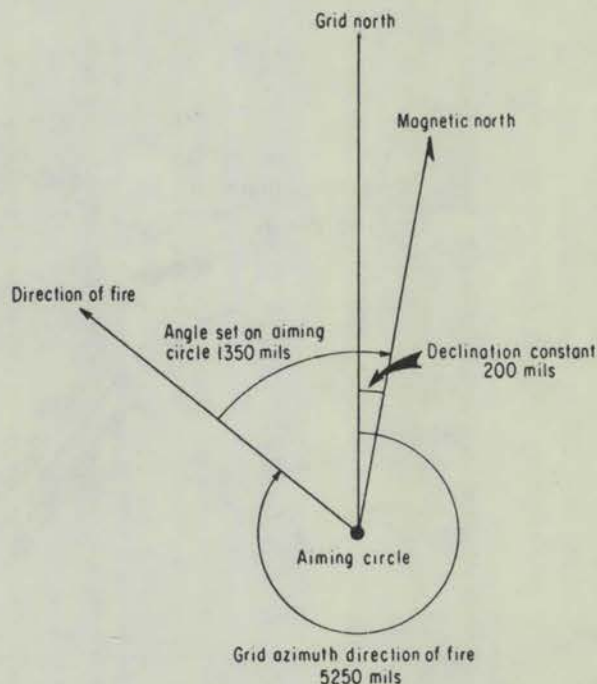


Figure 18. Orienting by grid azimuth.

c. *Orienting by Orienting Angle.* In order to lay the battery by orienting angle, an orienting line must have been established. The orienting line must be materialized on the ground by a stake over which the aiming circle will be set (orienting station) and a distant point which may be a stake or a terrain feature. The orienting angle is the horizontal, clockwise angle from the direction of fire to the orienting line. The executive officer is normally given the orienting angle but, if he knows the azimuth of the orienting line and the azimuth of the line of fire, he can compute the orienting angle by subtracting the azimuth of fire from the azimuth of the orienting line. The upper motion is used to set the orienting angle on the aiming circle and the lower motion is used to sight the aiming circle on the end of the orienting line. The 0-3200 line is now established parallel to the line of fire.

Example: Azimuth of orienting line is 1,300 mils. The azimuth on which the executive officer wishes to lay is 2,500 mils. The orienting

angle is 5,200 mils ($1,300 + 6,400 = 7,700 - 2,500 = 5,200$). The aiming circle is set up over the orienting station. The upper motion is used to set off 5,200 mils on the aiming circle. The executive officer then sights on the end of the orienting line using the lower motion. The 0-3200 line of the aiming circle is now oriented (fig. 19).

d. *Orienting by Aiming Point and Deflection.* In some cases, when a battery is occupying a position, the executive officer is given an aiming point and deflection on which to lay. To orient the aiming circle, the executive officer merely sets off the deflection, using the upper motion, and sights on the aiming point, using the lower motion. The 0-3200 line of the aiming circle is then parallel to the direction of fire.

48. Reciprocal Laying

a. *General.* Reciprocal laying is a procedure by which the 0-3200 line of one instrument (aiming circle) and the 0-3200 line of another

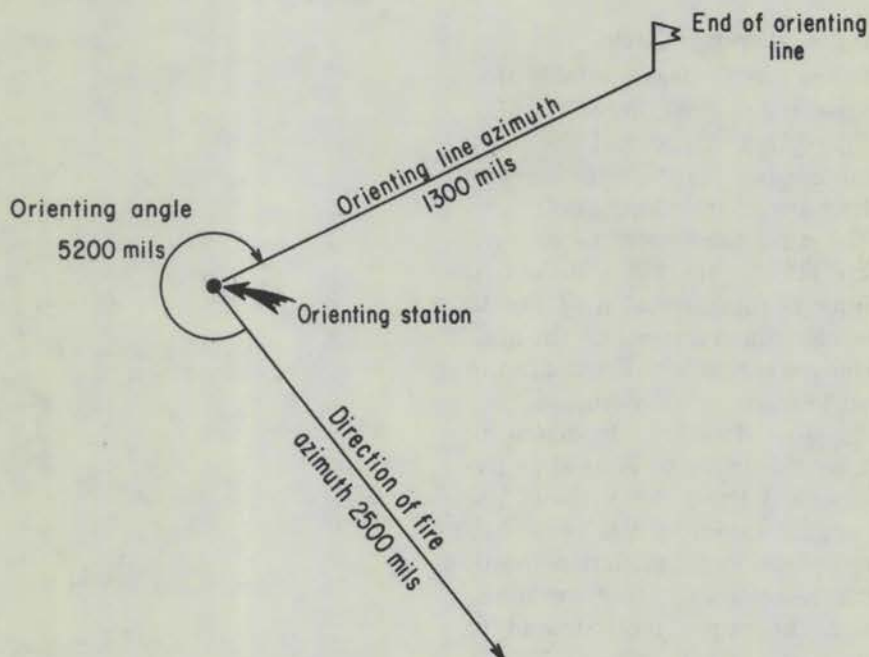


Figure 19. Orienting by orienting angle.

instrument (panoramic telescope) are laid parallel. When the 0-3200 lines of an aiming circle and a panoramic telescope are parallel and the piece has been properly boresighted, the tube of the piece is parallel to both 0-3200 lines. The principle of reciprocal laying is based

on the geometric theorem which states that if two parallel lines are cut by a transversal, the alternate interior angles are equal. The parallel lines are the 0-3200 lines of the instruments; the transversal is the line of sight between the two instruments. The alternate interior angles

are the equal deflections placed on the instruments (fig. 20).

b. *Procedure.* After the 0-3200 line of the aiming circle has been established parallel to the direction of fire (par. 47), the instrument operator, using the upper motion, sights on the objective lens of the panoramic telescope, reads the deflection on the azimuth and azimuth micrometer scales, and announces the deflection to the gunner on the piece. The gunner sets off the announced deflection on the panoramic telescope and **causes**

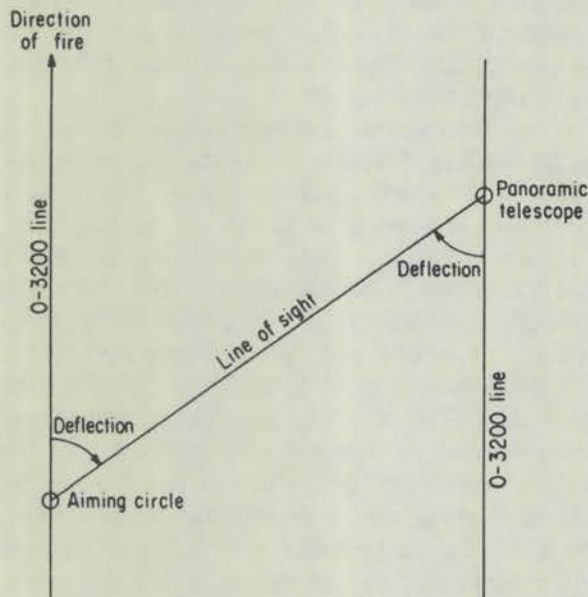


Figure 20. Principle of reciprocal laying.

the piece to be moved until the telescope is sighted on the objective lens of the aiming circle. Because the panoramic telescope is offset laterally from the axis about which the carriage is moved, the telescope is displaced horizontally. When the telescope has been sighted on the aiming circle, the gunner reports ready for recheck and the instrument operator again sights on the objective lens of the telescope and reads and announces the deflection. This procedure is repeated until the gunner reports a difference of zero mils between successive deflections. The piece has then been laid.

Example: The following illustrates the commands and procedures used in reciprocal laying:

- (1) *Executive*—BATTERY ADJUST, AIMING POINT THIS INSTRUMENT.

- (2) *Gunner of number 3*—NUMBER 3, AIMING POINT IDENTIFIED. (All gunners report in this manner. For brevity, only the commands of number 3 will be shown here. Other pieces are laid in the same manner.)
- (3) *Executive*—NUMBER 3, DEFLECTION 3091. (The executive had referred the aiming circle to the objective lens of the telescope.)
- (4) *Gunner of number 3*—NUMBER 3, DEFLECTION 3091. (The gunner sets off 3,091 on his telescope and **causes the piece to be moved** until he is sighted on the aiming circle. In the meantime, the executive is laying other pieces.) NUMBER 3 READY FOR RECHECK.
- (5) *Executive*—NUMBER 3, DEFLECTION 3093.
- (6) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093, 2 MILS. (This indicates a 2-mil difference between this deflection and the previous deflection.) After setting off 3,093 and traversing the piece until the telescope is again sighted on the aiming circle, the gunner announces NUMBER 3 READY FOR RECHECK.
- (7) *Executive*—NUMBER 3, DEFLECTION 3093.
- (8) *Gunner of number 3*—NUMBER 3, DEFLECTION 3093. ZERO MILS.
- (9) *Executive*—NUMBER 3 IS LAID. (Unit standing operating procedure will specify the deflection at which aiming posts will be placed upon completion of laying.)

49. Recording Laying for Direction

a. Under normal circumstances, after the battery has been laid parallel, the executive officer will cause each piece to refer to a common deflection and the crew to set out aiming posts along the resulting line of sight (the tube is not moved). By following this procedure, each piece now has an aiming point and deflection which, when used will cause the tube to be pointed in the direction in which it was initially laid without again going through the process of reciprocal laying. Furthermore, the direction in which the battery is initially laid and the corresponding deflection are used as

references from which fire direction center (FDC) can derive firing deflection for future targets.

b. It is desirable to have the far aiming post at least 100 meters from the piece. The near aiming post must be placed at one-half the distance from the piece to the far aiming post.

c. The referred deflection at which to place aiming posts that have been found to be most convenient are shown below:

<i>Weapons</i>	<i>Deflection</i>
105-mm Howitzer -----	2600 or 2800
155-mm Howitzer -----	2400 or 2600
8-inch Howitzer -----	2600
175-mm Gun -----	2600

d. If the aiming posts of an individual piece cannot be placed at the announced common deflection because of ground contour, foliage, trees, or other conditions, the gunner turns the azimuth micrometer knob until the azimuth scale is on another even 100-mil graduation. The aiming posts are alined at this new deflection. The chief of section reports the altered deflection to the executive officer: NUMBER (so-and-so), AIMING POSTS AT (so many hundred), DEFLECTION (common deflection) in LAKE (or other reason). The executive officer will then command NUMBER (so-and-so), DEFLECTION 2800, REFER. At this command, the gunner loosens the slipping azimuth scale locking screw and moves the slipping azimuth scale to the common deflection. He then tightens the locking screw and verifies the adjustment.

e. If a piece is not equipped with a slipping scale on the sight and the crew is unable to place its aiming posts on the common deflection announced because of ground contour, foliage, trees, or other conditions, the chief of section determines the deflection at which the piece can be referred to aiming posts and the posts are alined at this deflection. The chief of section reports this deflection to the executive and the reason therefore; e.g., NUMBER (so-and-so), AIMING POSTS AT DEFLECTION (so much), DEFLECTION 2800 IN RAVINE. (The deflection at which the aiming posts are placed should be a multiple of 100 mils.) The gunner then determines the correction for the piece and applies it as a constant correction to any deflection command by the executive. This

constant should be recorded by the gunner and the battery recorder.

Example: The battery has been laid and commanded to refer to aiming posts at deflection 2,800. All gunners can comply except the gunner of number 2 piece, whose visibility is blocked by foliage. Number 2 piece gunner has emplaced the aiming posts at 2,400 and reported this data to the executive. The constant correction for number 2 piece is minus 400 (2,400-2,800). The executive officer now gives the command for a fire mission, which includes DEFLECTION 2912. All pieces in the battery except number 2 are laid on the announced deflection 2,912. Number 2 is laid on deflection 2,512 (2,912-400).

f. As soon as the battery has been laid parallel and referred to aiming posts, the executive officer will have the gunners of all pieces refer to a distant aiming point, if one is available. For example, he may command AIMING POINT, STEEPLE, RIGHT FRONT, REFER, RECORD REFERRED DEFLECTION. The gunners refer to the steeple and read and report the deflection; e.g., NUMBER 3, STEEPLE, DEFLECTION (so much). These deflections are recorded by the chief of section and the battery recorder for future use. Should the aiming posts of any section be rendered useless, the executive officer can maintain parallelism and control of direction by using this deflection and aiming point. This information is used for reemplacing the aiming posts at the earliest possible time.

50. Verifying Laying for Direction

a. After the battery has been laid, the executive officer should direct checks to insure that the pieces have been laid parallel and in the proper direction.

b. Parallelism can be checked by having the gunners lay all pieces on the common deflection and then, by pairs, refer to each other's panoramic telescope. If the deflections read by the two gunners agree, the pieces are laid parallel. Each piece should check with at least two other pieces.

c. As soon as time permits, the executive officer should make the following check:

- (1) With the aiming circle (or instrument used to lay the battery initially) still

set up, the executive officer commands NUMBER (so-and-so) (base piece), AIMING POINT THIS INSTRUMENT, REFER.

- (2) The gunner of the piece indicated turns the sight of the piece until the line of sight is on the designated instrument and announces the reading on the sight scale as NUMBER (so-and-so), DEFLECTION (so much).
 - (3) The executive officer sets this reading on the azimuth and the azimuth micrometer scales of his instrument and, with the lower motion, sights on the panoramic telescope of the piece indicated, thus establishing the 0-3200 line of his instrument parallel to the direction of fire. He now verifies the azimuth or orienting angle by one of the following procedures:
 - (a) If the battery was laid on an azimuth, the executive officer centers the needle, using the upper motion, and reads the azimuth and azimuth micrometer scales. This reading is subtracted from the declination constant. The result is the azimuth on which the battery is laid. If the azimuth determined is within 2 mils of the initial azimuth, the laying may be considered verified for direction.
 - (b) If the battery was laid on an orienting angle, the executive officer sights on the end of the orienting line, using the upper motion. If the resulting reading on the azimuth and azimuth micrometer scales agree with the initial orienting angle, the laying is considered verified for direction.
 - (4) The executive officer repeats that command in (1) above to each of the other pieces in turn, at the same time referring with the aiming circle to the panoramic telescope of each piece.
 - (5) If the deflection read by the gunner does not agree with that read by the executive officer, the executive officer can correct the laying of that piece for direction by giving the gunner the proper deflection.
- d. A number of other similar techniques may be used to verify laying. A knowledge of the

general direction of fire and a visual check of the laying is the minimum permissible verification.

51. Conversion of Data for Direction

a. *Preparation for Converting Data.* If no direction has been given the executive officer upon occupation of position, he lays the battery parallel in a direction which appears to be most appropriate, considering his knowledge of the situation, and records a referred deflection. When a fire command prescribing a different direction, a different method of laying, or both, is received, he can accomplish the change by announcing a new deflection with reference to the aiming posts. In order to be prepared for any eventuality, the executive—

- (1) Determines the azimuth on which the battery is laid.
- (2) Determines the orienting angle on which the battery is laid (if an orienting line has been established).
- (3) Has the base piece gunner measure the deflection (refer) to visible aiming points. (Has the gunner of another piece also measure these deflections to serve as a check against large errors.)

b. *Shift From One Grid Azimuth to Another.* If the battery is laid on an azimuth and a command for another azimuth is received, the executive computes the difference between the two azimuths. He next applies this difference to the original deflection in the proper direction; an increase in grid azimuth decreases the deflection, and a decrease in grid azimuth increases the deflection (fig. 21). The result is the deflection necessary to lay the battery on the new grid azimuth.

c. *Shift From One Orienting Angle to Another.* If the battery is laid on an orienting angle and a command for another orienting angle is received, the executive computes the difference between the two orienting angles. He next applies this difference to the original deflection in the proper direction; an increase in orienting angle increases the deflection, and a decrease in orienting angle decreases the deflection (fig. 22). The result is the deflection necessary to lay the battery on the new orienting angle.

d. *Shift From an Azimuth to an Orienting Angle.* After the battery has been laid parallel on an azimuth, an orienting line may be established and

Battery is laid
on azimuth 5400,
deflection 2800

Battery is laid
on azimuth 1200,
deflection 2800

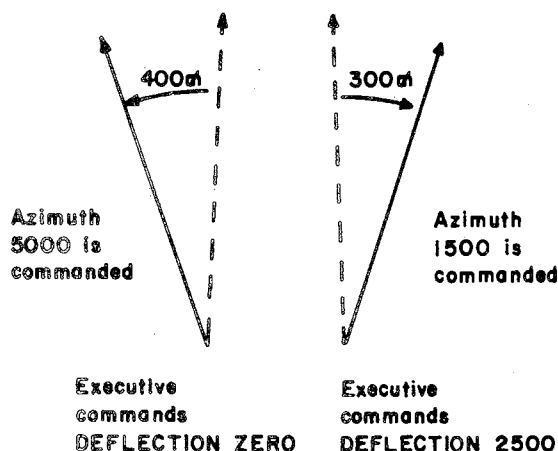


Figure 21. Shifts to compensate for difference in grid azimuth.

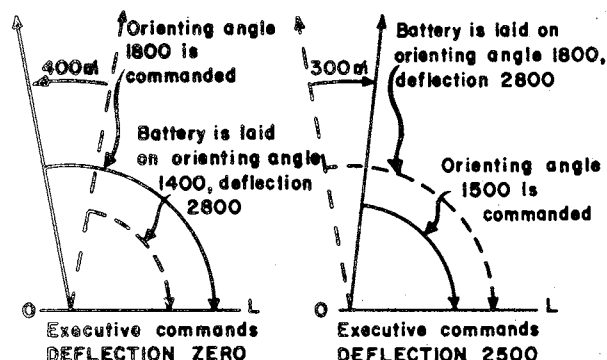


Figure 22. Shifts to compensate for difference in orienting angles.

an orienting angle announced. This will necessitate a shift from grid azimuth to the announced orienting angle. The executive officer sets the aiming circle over the orienting station and measures the orienting angle on which the battery is laid. He compares this angle with the announced orienting angle, commands an appropriate deflection, and has the aiming posts realigned.

52. Laying the Battery Without an Aiming Circle

At times, it may be necessary to lay the battery without using an aiming circle. Among the situations which would indicate use of the methods described below are lack of a usable aiming circle and the lack of time to lay by normal procedures.

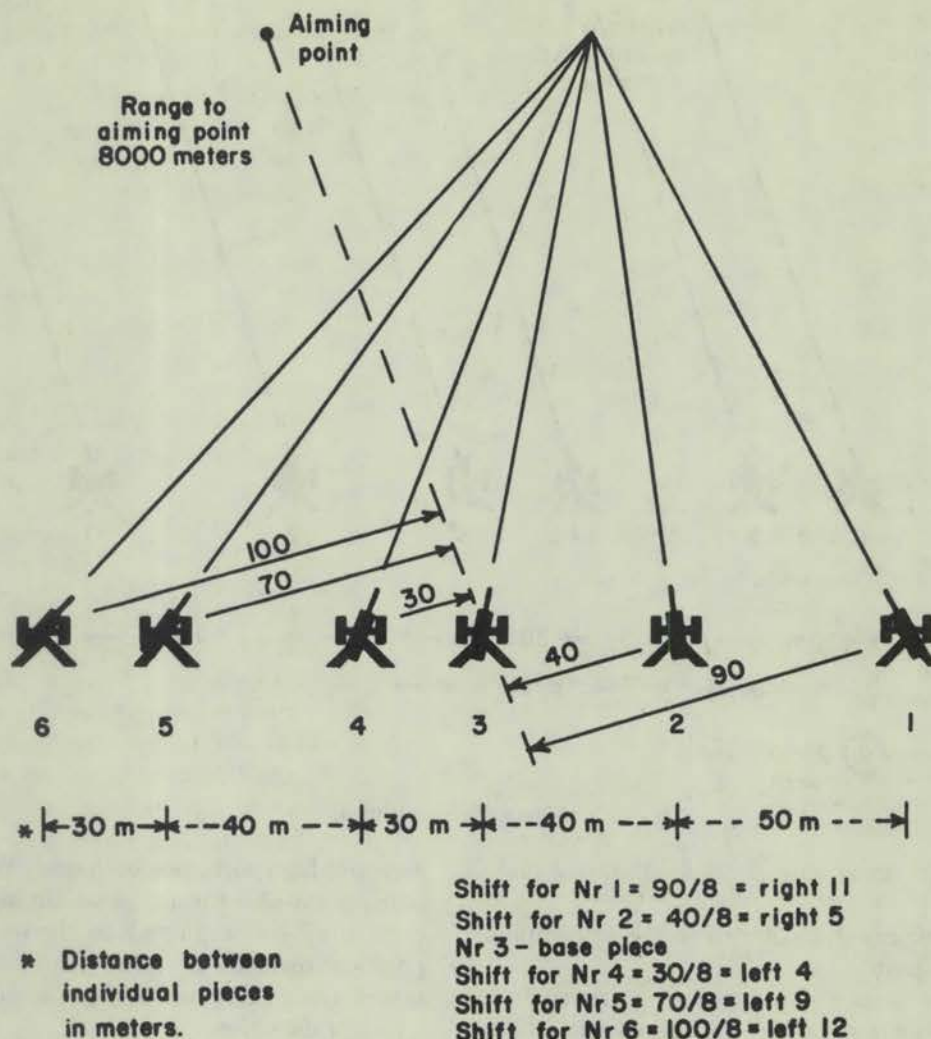
a. Aiming Point and Deflection. There are two methods the executive officer can use to lay by aiming point and deflection.

- (1) The executive officer commands, to the first piece prepared for action, NUMBER (so-and-so), AIMING POINT (so-and-so), DEFLECTION (so much). The gunner sets the announced deflection and sights on the aiming point by **moving** the tube. This action lays the tube in the desired direction. The executive officer then commands ON NUMBER (so-and-so), LAY PARALLEL. The gunner then lays the other pieces reciprocally with the panoramic telescope in the same manner as laying with the aiming circle (par. 48).

- (2) The executive may command AIMING POINT (so-and-so), DEFLECTION (so much). All gunners set off the announced deflection and sight on the aiming point by **moving** the tube. If the aiming point is at the flank of the battery and a common deflection is given to all pieces, the battery can be considered as laid parallel. If the aiming point is to the front, the sheaf is converged at aiming point range in the target area as shown by the exaggerated diagram in 1, figure 23. The convergence is corrected, and the sheaf is formed parallel by means of individual shifts (2, fig. 23).

Example: It is desired to form the sheaf parallel on the number 3 piece (fig. 23). The shifts are determined for each piece by using the mil relation, R being the range to the aiming point and W being the perpendicular distance from the piece concerned to a line through the aiming point and number 3 piece. If the aiming point is to the rear, the sheaf will diverge. Individual shifts are computed as above to form the sheaf parallel.

- (3) To determine the deflection on which to sight on the selected aiming point, the desired direction of fire may be compared with the azimuth to the aiming point. For example, if the azimuth to the aiming point is 600 mils left of the direction of fire, the deflection would be 2600 (3200-600). If the azimuth to the aiming point



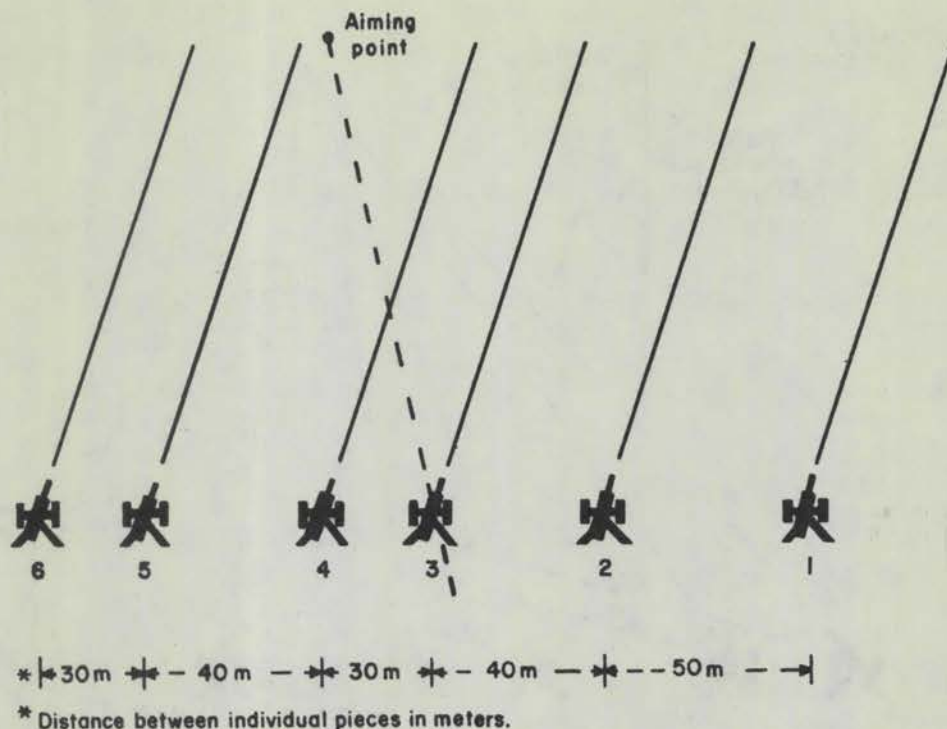
① Sheaf converged

Figure 23. Opening a converged sheaf by individual shifts to obtain a parallel sheaf.

is 600 mils right of the azimuth of fire, the deflection would be 600 (0—600).

b. *M2 Compass.* The command to the executive officer to lay the battery by azimuth is LAY ON

AZIMUTH (so much). This command is not repeated. The executive officer places the compass on a steady object, away from objects which might affect the magnetic needle and in a place where it



(2) Parallel sheaf

Figure 23—Continued.

can be used as an aiming point for the base piece. He then—

- (1) Measures the azimuth to the telescope of the base piece.
- (2) Subtracts the announced azimuth from the azimuth which he measured (adding 6,400, if necessary).
- (3) Uses the remainder (minus 3,200, if necessary) as the deflection and the compass as an aiming point to lay the base piece (fig. 24).
- (4) Orders the gunner of the base piece to lay the other pieces reciprocally.

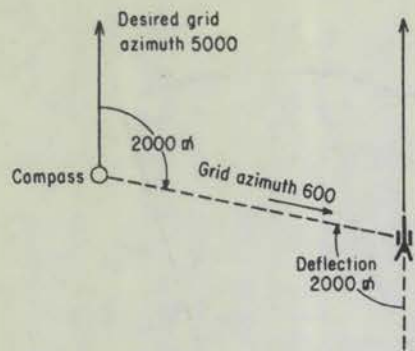
53. Laying by Aircraft, High Airburst, or Flare

a. No specific command is prescribed for laying the battery by sighting on aircraft, airburst, or flare. The executive may lay the battery initially for direction by sighting with an instrument on the

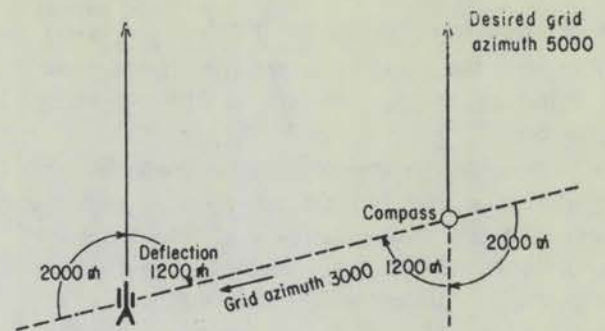
aircraft, high airburst, or flare. When no visible point is suitable for use as an aiming point, an aircraft may be employed to fly over the battery position toward, or away from, a point in the target area. The line of flight is used to establish a line of direction.

b. The high airburst or flare should be over the target area. The high airburst is fired by another unit, which has been laid previously for direction. The flare may be fired by an air or a ground observer.

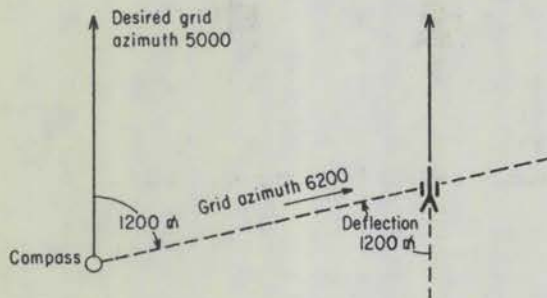
c. The executive sets up an instrument (usually in rear of the battery center) where it can be used as an aiming point by all pieces. He zeros the azimuth and the azimuth micrometer scales, and, by using the lower motion, places the vertical hairline on the aircraft, burst, or flare at the proper instant. Using the upper motion, the executive lays the pieces reciprocally.



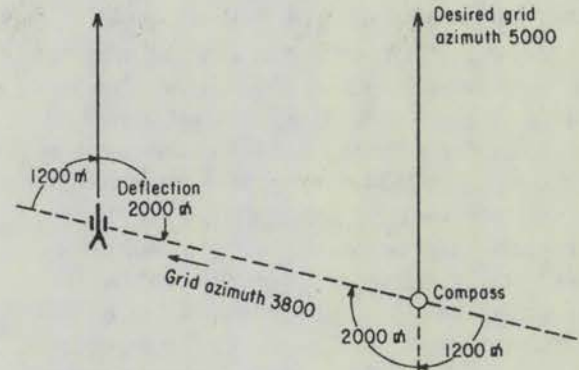
① Compass to left front. Deflection to lay tube parallel, 2000 mils.



② Compass to right front. Deflection to lay tube parallel, 1200 mils.



③ Compass to left rear. Deflection to lay tube parallel, 1200 mils.



④ Compass to right rear. Deflection to lay tube parallel, 2000 mils.

Figure 24. Use of M2 compass to lay by grid azimuth.

Section II. MINIMUM QUADRANT ELEVATION

54. Introduction

a. The safe firing of a battery is the responsibility of the battery executive officer. In garrison, a safety officer is appointed and is responsible for insuring that persons and property are not endangered by fire. In combat, the S3 is responsible to determine a quadrant elevation which will insure that rounds clear friendly troops and no-fire lines.

b. This section sets forth procedures required to clear the mask in the firing battery area. The executive officer will determine and report to the FDC, the minimum quadrant elevation to clear the mask *visible from the battery position*. (For VT fuzes, the minimum QE is computed at mask range or VT arming time range, whichever is applicable.) The minimum quadrant

elevation must be computed for *each charge* to be fired, the computation varying with the type of fuze (VT or any other type).

c. The minimum quadrant elevation to clear the visible mask must be compared to the minimum quadrant elevation, determined by the S3 or safety officer, required to clear minimum range lines, intermediate crests, or no-fire lines. The largest minimum quadrant elevation is used.

55. Measuring Angle of Site Mask

As soon as a piece is laid for direction, the chief of section determines the angle of site to the highest mask for his piece, as prescribed in the field manual appropriate for the weapon, and reports it to the executive officer.

56. Measuring Range to Mask

Range to the mask is determined to the nearest hundred meters by one of the following methods:

a. *Obtaining Distance From a Map.* To obtain distance to a mask from a map, plot the location of the position area and determine the highest point of the mask. Measure the distance with an appropriate scale. This method is fast and accurate and is not affected by adverse terrain features as in *b* and *c* below.

b. *Pacing the Distance.* Pacing the distance to a mask requires no equipment; time required to measure the range will depend on distance to mask and accessibility of route to mask.

c. *Use of the Mil Relation.* Determining the range to a mask by using the mil relation is a particularly good method when the tactical situation does not permit actual measurement by one of the methods in *a* or *b* above. The mil relation method may be accomplished by the use of the panoramic telescopes of the flank pieces, by one aiming circle and one panoramic telescope, or by two aiming circles. Usually, the most practical means is the use of the panoramic telescopes of the flank pieces. For example, the battery has been laid parallel; the paced distance between flank pieces is 150 meters (fig. 25).

- (1) The gunners of the flank pieces refer to exactly the same point on the mask.
- (2) Each of the flank gunners announces the deflection to the point on the mask from his piece.
- (3) The apex angle is determined from these two deflections as indicated in figure 25.
- (4) The range to the mask is determined by dividing the battery front in meters by the apex angle in mils (the mil relation).

d. *Estimation.* If none of the above methods of determining the range to the mask is possible, the range is estimated.

57. Computation of Minimum Quadrant Elevation for Firing With Fuzes Other Than VT

a. Army Regulations require that a projectile fired with a fuze other than VT clear

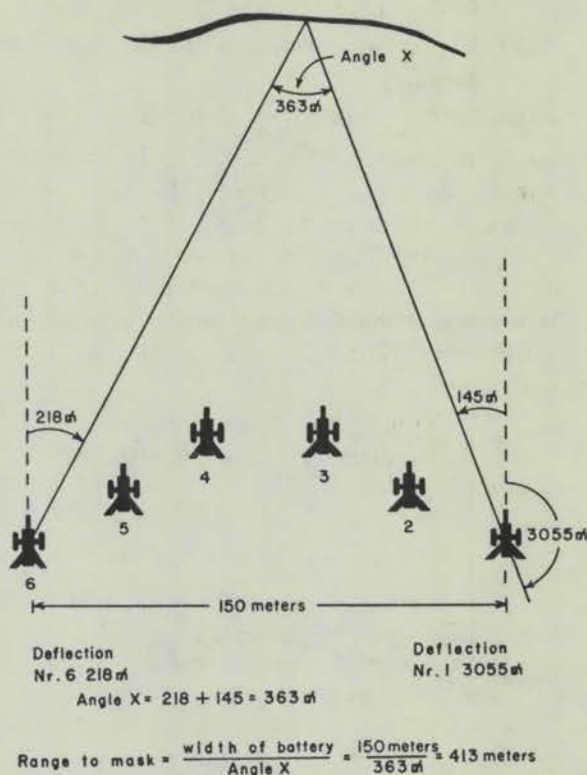


Figure 25. Determining range to mask.

friendly troops by 5 meters vertically and that the quadrant elevation computed for the point 5 meters above the friendly troops be modified by adding 2 forks.

b. The computation of minimum quadrant elevation involves the addition of the following elements.

- (1) Greatest angle of site measured by chiefs of section.
- (2) Vertical angle corresponding to 5-meter vertical clearance. This angle is computed by using the mil relation (5 meters divided by mask range in thousands of meters). Unless informed otherwise, the executive officer assumes that the mask is occupied by friendly troops.
- (3) Complementary angle of site for elements (1) and (2) (use comp site factor for mask range—interpolate for range to nearest 100 meters).

- (4) Determine site to mask by adding items (1), (2) and (3).
- (5) Elevation corresponding to range to mask.
- (6) Two forks at range to mask.

The sum of elements (1) and (2) is the angle of site to the point 5 meters above the mask. The sum of elements (1), (2), and (3) is the site to the point 5 meters above the mask. The sum of (4), (5) and (6) is the QE to the point 5 meters above the mask and is reported as the minimum quadrant elevation in the executive officer's report.

Example: 155-mm howitzer; charge 5; range to mask, 1,100 meters, angles of site reported by chiefs of section, +35, +36, +35, +34, +36, +35.

Solution:

- (1) Greatest angle of site reported ---- +36.0 mils
- (2) Vertical angle corresponding to
5-meter vertical clearance (5/1.1) ---- +4.5
- (3) Complementary angle of site (+0.001
× 40.5) ----- +0.0
Total ----- 40.5
- (4) Site for mask range 40 (36.0 + 4.5 + 0.0 =
40.5).
- (5) Elevation for mask range ----- 43
- (6) Two forks at mask range ----- 2
Total ----- 85
Minimum quadrant elevation reported - 85 mils

c. If the mask has sectors with significantly different altitudes, it will be necessary to compute more than one minimum quadrant elevation for the sector of fire. In this case the executive officer reports, for example, AZIMUTH 4850 TO 5200, MINIMUM QUADRANT ELEVATION CHARGE 5, 79, AZIMUTH 5200 TO 5650, MINIMUM QUADRANT ELEVATION CHARGE 5, 86.

d. A single narrow obstruction, such as a tree, which will mask only one piece at a time, is not considered in computing minimum quadrant elevation. If a piece cannot fire safely, it is called out of action.

58. VT Fuzes

a. Fuzes of the M513 and M514 series are controlled variable time (CVT) fuzes. A time setting from 5 to 100 seconds may be set on all

fuzes of these series. The VT element in a CVT fuze is armed at 2 seconds after firing or from 3 to 5.5 seconds prior to the time set on the fuze, whichever is later.

b. Fuze M513A1 and fuze M514A1 may be set on point detonating (PD). When so set, they are treated as fuze quick.

59. Computation of Minimum Quadrant Elevation for Firing With VT Fuzes (Low-Angle Fire)

a. When the time set on a VT fuze is greater than the time of flight to the mask plus 5.5 seconds, the minimum QE computed for other fuzes is used.

b. If fuze M513A1 or M514A1 is set on point detonating, the minimum QE computed for other fuzes is used.

c. When the time set on the fuze is equal to or less than the time of flight to the mask plus 5.5 seconds, the following procedures apply:

- (1) Vertical clearances for low-angle fire are—

Weapon	Vertical clearance
105-mm howitzer	80 meters
155-mm howitzer	100 meters
8-inch howitzer	150 meters
175-mm gun	150 meters

Note. These clearances should be increased by 50 percent for firing over marshy or wet ground, and by 100 percent for firing over water.

- (2) The range used in all computations is the mask range (nearest 100 meters) or the range corresponding to a 2-second time of flight, whichever is greater. The range corresponding to a 2-second time of flight is determined from the firing tables; if 2.0 seconds is not listed, the range corresponding to the next higher time of flight is used.
- (3) The elements used to compute the minimum QE are—
 - (a) Greatest angle of site reported by chiefs of section.
 - (b) Vertical angle corresponding to vertical clearance. This angle is computed by dividing the vertical

clearance from (1) above by the range from (2) above in thousands of meters.

- (c) Complementary angle of site for elements (a) and (b) above. Complementary angle of site factor corresponds to the range from (2) above (Interpolate for ranges not listed).

- (d) Determine site to mask by adding (a) (b) and (c) above.

- (e) Elevation corresponding to range from (2) above.

- (f) Two forks corresponding to range from (2) above.

- (4) The minimum quadrant elevation reported is the sum of the elements (d) through (f) above.

Example 1: 155-mm howitzer, charge 5, fuze M514, range to mask 1,700 meters, fuze setting 10.0 seconds; angles of site reported by chiefs of section +40, +39, +40, +38, +39, +40; ground is dry.

Solution: Time of flight to mask (range 1,700) (5.0 seconds) plus 5.5 seconds is 10.5 seconds. Range corresponding to 2.0 seconds is 700 meters. Use 1,700 meters.

(1) Greatest angle of site	-----+40.0
(2) Vertical angle corresponding to 100-meter vertical clearance (100/1.7)	----- 58.8
(3) Complementary angle of site (98.8 × 0.003)	----- 0.3
Total	----- 99.1
(4) Site at mask range	----- 99
(40.0 + 58.8 + 0.3 = 99.1)	
(5) Elevation for mask range	----- 70
(6) Two forks at mask range	----- 4
Total	----- 173

Minimum quadrant elevation reported 173 mils

Example 2: 155-mm howitzer, charge 5, fuze M514, range to mask 500 meters, fuze setting 0; angles of site reported by chiefs of section +41, +45, +43, +45, +44, +44; ground is dry.

Solution: Range corresponding to 2.0 seconds is 700 meters. Use 700 meters.

(1) Greatest angle of site	-----+45.0
(2) Vertical angle corresponding to vertical clearance (100/0.7)	----- 142.9

(3) Complementary angle of site (187.9 × 0.0)	----- 0.0
Total	----- 187.9

(4) Site at mask range (45.0 + 142.9 + 0.0)	----- 188
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(5) Elevation for 700 meters	----- 27
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(6) Two forks at 700 meters	----- 2
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Total	----- 217
-------	-----------

Minimum quadrant elevation reported 217 mils

60. Minimum Quadrant Elevation Card

a. The minimum quadrant elevation card contains data which facilitates the computation of minimum quadrant elevation by the executive officer. The table on the card lists (in column headed EL), for all charges and selected ranges, the sum of elevation, two forks, the vertical angle corresponding to the appropriate vertical clearance, and the complementary angle of site for +300 mils angle of site. On one side of the card are the data to be used with all fuzes other than VT. On the other side of the card are the data to be used with fuze VT. The side of the card to be used with fuze VT also lists the time of flight plus 5.5 seconds for each listed range. When the time set on the VT fuze is greater than the time listed on the card, the minimum quadrant elevation for fuzes other than VT is used.

b. To determine the minimum quadrant elevation the executive officer uses the following procedure:

- (1) Enter the table at the mask range and determine the value in the column(s) headed EL for the appropriate charge(s). If the mask range is not listed, enter at the next higher or lower listed range, whichever has the greater value of elevation.
- (2) Select the greatest angle of site reported by the chiefs of section.
- (3) Add the values determined in (1) and (2) above. The sum is the minimum quadrant elevation.

Example: 155-mm howitzer; range to the mask 900 meters. Angles of site reported by the chiefs of section, +80, +78, +79,

+80, +78, +79. Determine the minimum quadrant elevation for charge 5, fuze M500.

Solution: Enter table at range 1,000 meters (900 meters not listed).

- (1) Value from the table 46
 (2) Greatest angle of site reported --- +80
 Minimum quadrant elevation ----- 126 mils

c. Examples of minimum quadrant elevation cards with appropriate instructions are shown below:

Minimum Quadrant Elevation (Less Angle of Site) 155-mm How M114 Shell HE M107 Fz M514 FT 155-Q-3

Mask	Chg 3		Chg 4		Chg 5		Chg 6		Chg 7	
Range	El	Ti	El	Ti	El	Ti	El	Ti	El	Ti
200	211	7.0	201	7.0	172	6.0	135	6.0	111	6.0
400	211	7.0	201	7.0	172	7.0	135	7.0	111	7.0
600	211	8.0	201	8.0	172	8.0	135	7.0	111	7.0
800	185	9.0	169	9.0	158	8.0	135	8.0	111	7.0
1000	177	10.0	156	9.0	141	9.0	127	8.0	111	8.0
1200	175	11.0	150	10.0	135	9.0	115	9.0	105	8.0
1400	180	11.0	152	11.0	132	10.0	110	9.0	97	9.0
1600	189	12.0	155	11.0	132	11.0	107	10.0	92	9.0
1800	200	13.0	160	12.0	134	11.0	105	10.0	90	9.0
2000	210	14.0	167	13.0	138	12.0	106	11.0	88	10.0
2500	249	16.0	191	15.0	155	13.0	114	12.0	88	11.0

Instructions:

1. Enter table with range to mask and at the appropriate charge(s). If range to mask is not listed, enter at the next higher or lower listed range, whichever has the greater value listed in the column headed El.
2. To obtain the MQE, add the greatest angle of site reported by the chiefs of section to the value listed in the column headed El.
3. The MQE determined using this table is used whenever the fuze setting is equal to or less than the value in the column headed Ti. If the fuze setting is greater than the value under Ti, use the MQE determined for fuze M520.

*Minimum Quadrant Elevation (Less Angle of Site)
 155-mm How M114 Shell HE M107, Fz M51, M500,
 M520, FT 155-Q-3*

Mask	Charge				
Range	3	4	5	6	7
200	41	37	34	32	30
400	42	35	29	24	20
600	53	42	33	24	20
800	66	50	39	28	21
1000	82	61	46	32	24
1200	96	71	56	36	26
1400	112	82	64	42	30
1600	130	96	73	47	33
1800	146	108	82	52	37
2000	163	120	91	58	40
2500	211	153	117	76	50

Instructions:

1. Enter table at mask range and at the appropriate charge(s). If mask range is not listed enter at next higher or lower listed range whichever has the greater value in the body of the table.
2. To obtain the MOE, add the greatest angle of site reported by the chiefs of section, to the value taken from the body of table.

Section III. MEASURING AND REPORTING DATA

61. Introduction

The battalion fire direction center requires data from the firing battery for various purposes, such as construction of firing charts and checks on laying. The executive officer requires the same data for the charts at the battery fire direction center. The battery executive officer is responsible for reporting the necessary data from the firing battery to fire direction center. This section describes the executive officer's duties in measuring and reporting data.

62. Executive Officer's Report

a. As soon as possible after occupying position and without interfering with firing, the executive officer reports the following data to fire direction center:

- (1) BATTERY IS LAID.
- (2) AZIMUTH (ORIENTING ANGLE)
----- DEFLECTION -----
- (3) MINIMUM QUADRANT ELEVATION(S), CHARGE -----
- (4) DISTRIBUTION OF PIECES, NUMBER 1, ----- METERS RIGHT (LEFT), ----- METERS BEHIND (IN FRONT OF) BATTERY CENTER: NUMBER 2, etc. The distances from battery center are reported to the nearest 5 meters. The direction in which the battery was laid is used as the reference direction. When time permits, the distribution of pieces should be submitted as a diagram or overlay (fig. 26).

b. In addition to the data reported in a above, the executive officer, as soon as time permits, will determine and report—

- (1) Amount, type, lot numbers of ammunition.
- (2) Weight of projectile.
- (3) Powder temperature.
- (4) Lateral limits (azimuths or deflections). These limits indicate the azimuths or deflections between which two-thirds of the pieces can be laid without shifting trails.

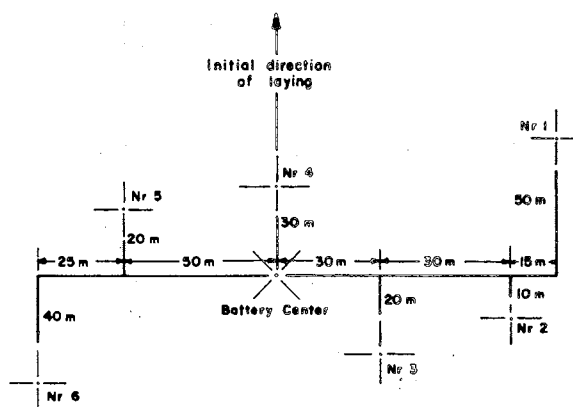


Figure 26. Position area sketch.

- (5) Maximum elevation, when high-angle fire is being used.

63. Reporting Adjusted Deflection

Upon completion of a registration, the executive officer should determine the adjusted deflection and report it to the fire direction center. The executive officer must determine the adjusted deflection before announcing END OF MISSION to the base piece. He goes to the base piece, verifies the sight picture, and reads the deflection on the sight. If the sight picture is not correct, he corrects it by referring the sight to the correct picture before reading the deflection on the sight. (The tube must not be moved.) He reports the deflection read as ADJUSTED DEFLECTION (so much).

64. Reporting Adjusted Azimuth

In order to report the adjusted azimuth, the executive officer must first determine the adjusted deflection (para. 63) and then compute the adjusted azimuth by comparing the adjusted deflection to the deflection corresponding to the azimuth on which the battery was initially laid and applying the difference to the azimuth on which the battery was laid.

Example: The battery is laid on azimuth 5,000, deflection 2,600. After adjustment on the registration point, the FDC commands REPORT ADJUSTED AZIMUTH. The executive

officer determines the adjusted deflection to be 2,715 mils. Deflection 2,715 is 115 mils to the left of deflection 2,600. Applying left 115 to azimuth 5,000, the adjusted azimuth is 4,885 mils. The executive officer reports ADJUSTED AZIMUTH 4885.

65. Measuring the Azimuth of the Direction of Fire

Upon completion of a registration and prior to announcing END OF MISSION, the executive officer should measure the azimuth and report the measured azimuth to FDC when required. The procedure for measuring and reporting the azimuth is as follows:

a. Set up the aiming circle away from magnetic attractions and where it can be seen from the base piece. Aline the 0-3200 line approximately parallel to the tube of the base piece.

b. Have the gunner of the base piece, using the panoramic telescope, lay the aiming circle parallel to the tube of the base piece.

c. Release the magnetic needle and center it, using the upper motion.

d. Determine the reading on the aiming circle and subtract that reading from the declination constant (adding 6,400, if necessary). The result is the measured azimuth.

66. Measuring the Orienting Angle

When an orienting line has been established, the executive officer should measure the orienting angle (fig. 27) upon the completion of a registration and report the measured orienting angle to FDC when required. The procedure for measuring the orienting angle is as follows:

a. Set the aiming circle over the orienting station.

b. Have the gunner of the base piece lay the aiming circle parallel to the tube of the base piece.

c. With the upper motion, the executive officer refers to the end of the orienting line.

d. The reading on the aiming circle (minus 3,200, if necessary) is the orienting angle.

67. Determining Instrument Direction

When the 0-3200 line of an aiming circle is pointing in an unknown direction and it is

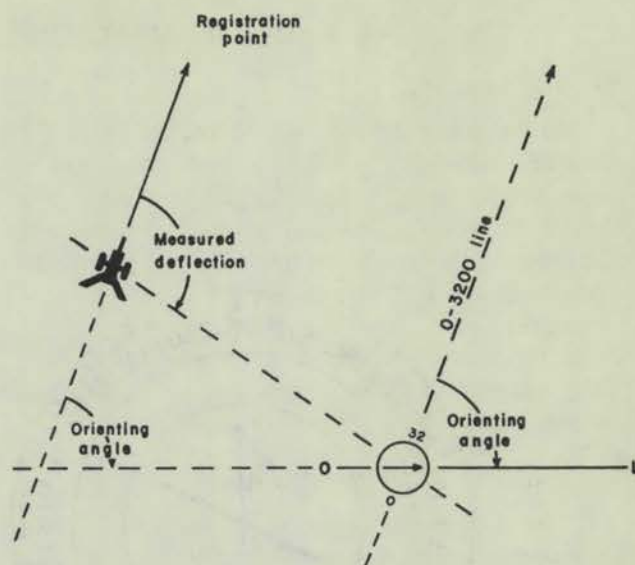


Figure 27. Measuring the orienting angle with aiming circle.

desired to determine the grid azimuth of that direction, the following procedure is used:

a. Release the needle and center it, using the upper motion.

b. Subtract the reading on the scales from the declination constant (adding 6,400, if necessary). The remainder is the grid azimuth of the 0-3200 line.

68. Measuring Azimuth to a Point

The following procedure is used to measure the azimuth to a point (fig. 28):

a. Place the aiming circle with the 0-3200 line in an approximate north-south direction with the large 0 of the scale toward the south.

b. With the upper motion, set off the declination constant (1, fig. 28).

c. Unlock the needle and, with the lower motion, center the needle thus directing the line of sight to magnetic north and the 0-3200 line of the instrument to grid north (2, fig. 28).

d. Lock the needle and, with the upper motion, refer the line of sight to the desired point. The grid azimuth to the designated point is read from the azimuth and azimuth micrometer scales (3, fig. 28).

e. For greater accuracy, repeat this operation three times and take the average of the readings.

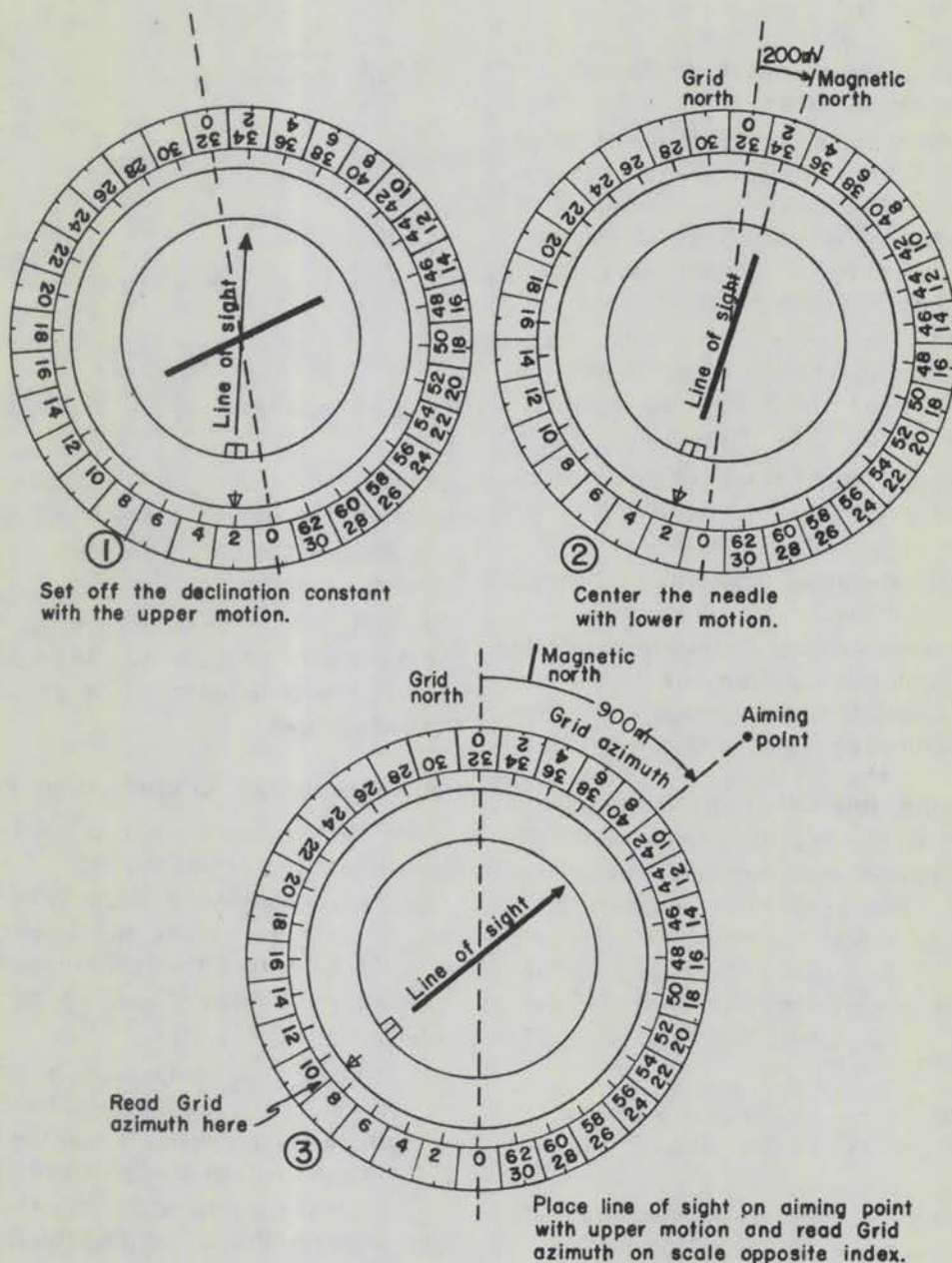


Figure 28. Measuring azimuth to a point.

69. Correction for Boresighting Error After Registration

a. Tactical considerations may require registration prior to making tests and adjustments. In such cases, pieces must be boresighted at the earliest practicable time, usually during a lull in firing. If boresighting discloses that the 0-3200 line of the sight (panoramic telescope) was not parallel to the tube, the executive officer must take corrective measures and report them to fire direction center.

b. When a deflection is read from a sight, or an azimuth is measured, the deflection or azimuth determined is that of the 0-3200 line of the sight. Only if the weapon is properly boresighted is the deflection or azimuth that of the tube. When FDC commands MEASURE THE AZIMUTH (ORIENTING ANGLE), the azimuth (orienting angle) of the tube is desired. Therefore, if the weapon is not properly boresighted, the azimuth (orienting angle) measured is false by the amount of the error in boresighting.

c. At the first opportunity after a registration, the base piece is boresighted. The tube is pointed at the aiming point (either a distant aiming point or the appropriate "butterfly" on the test target) and the sight is zeroed. If the sight is pointed to the right of the appropriate aiming point, it is apparent that the tube is pointed to the left of the 0-3200 line of the sight. It follows that any azimuth measured prior to this time was greater than the azimuth of the tube, and any orienting angle measured was smaller than the true orienting angle. If the sight is pointed to the left of the appropriate aiming point, measured azimuths are less than the azimuth of the tube and measured orienting angles are too large. To determine the amount of the error, with the tube still sighted on its aiming point, the sight is referred to its aiming point and the deflection is read. The referred deflection is compared to 3,200 and the difference is the amount of the error in boresight. The previously determined azimuths or orienting angles are corrected, the boresighting is completed, and the actions taken are reported.

Example 1: A battery has occupied position and before the base piece can be boresighted, a registration is conducted. At the conclusion of the registration, an adjusted deflection of 2,795 is reported and an azimuth of 1,800 is measured.

A short time later, the piece is boresighted. With the tube pointed at the aiming point and the sight zeroed, it is discovered that the sight is pointed to the right of the appropriate aiming point. The sight is then referred to the aiming point, and a deflection of 3,192 mils is read. The tube is pointed 8 mils to the left of the 0-3200 line of the sight (1, fig. 29). Therefore, the azimuth of the tube after registration was 1,792 ($1,800 - 8$). If

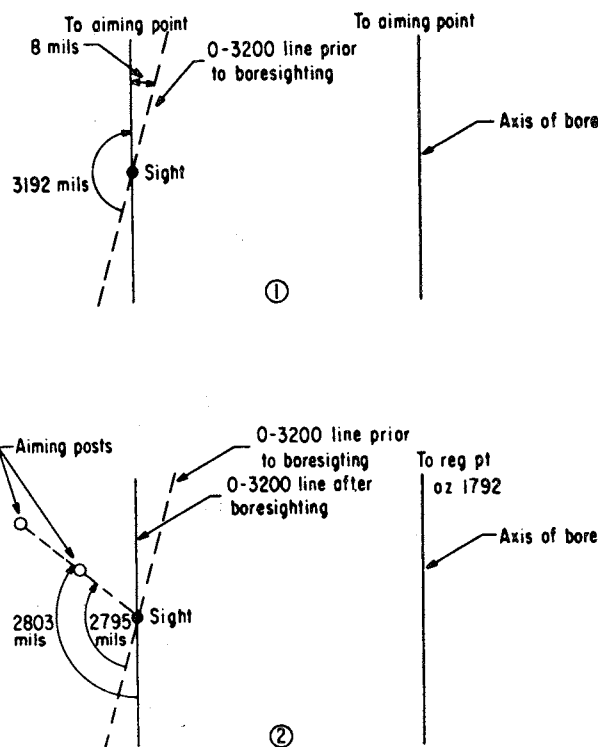


Figure 29. Example of error revealed by boresighting.

the boresighting is corrected, the deflection of 2,795 will not place the tube on azimuth 1,792; to correct this error, 8 mils must be added to the adjusted deflection and it becomes 2,803 (2, fig. 29). After correcting the boresighting, the executive officer makes the following report, ERROR OF 8 MILS IN BORESIGHTING ON NUMBER 3, CORRECT AZIMUTH WHEN LAID ON REGISTRATION POINT IS 1792, CORRECT ADJUSTED DEFLECTION IS 2803, BORESIGHTING HAS BEEN CORRECTED.

Example 2: Assume that in example 1 an orienting line had been established and that after the registration, an orienting angle of 853 mils had been measured. After determining the 8-mil

error in boresighting, the corrected orienting angle is 861 mils (fig. 30) and the following report is made, **ERROR OF 8 MILS IN BORESIGHTING OF NUMBER 3, CORRECT ORIENTING ANGLE IS 861, CORRECT ADJUSTED DEFLECTION 2803, BORESIGHTING HAS BEEN CORRECTED.**

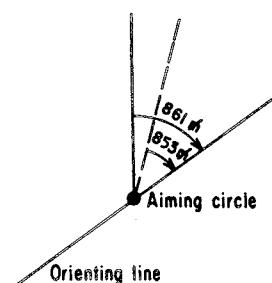
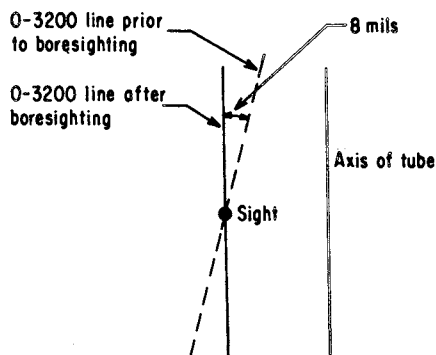


Figure 30. Example of error in orienting angle due to error in boresighting.

70. Site By Firing (Executive Officer's High Burst)

a. Upon completion of an observed firing chart registration with time fuze, the command **OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS**, followed by the adjusted data, may be received from fire direction center. This command indicates that FDC desires the executive officer to fire 3 rounds and to measure and report the observed angle of site to the mean burst center of the 3 rounds. The actions of the executive officer are as follows:

- (1) Sets up aiming circle or BC scope (battery commander's telescope) near the base piece.
- (2) Has the gunner lay the instrument reciprocally.

- (3) Determines and applies to the adjusted quadrant elevation the angle of site necessary to make the burst visible from the gun position.
- (4) Fires three rounds, using the announced adjusted deflection and time and the quadrant elevation determined in (3) above.
- (5) Measures with the instrument, the angle of site to each burst and computes the mean angle of site.
- (6) Reports the mean angle of site and the quadrant elevation fired to fire direction center.

b. See **paragraph 485** for associated FDC procedures.

71. Computation of Deflection Difference

a. A deflection difference is used to achieve a width of sheaf different than the width of the battery front. The sheaf is opened or closed on any desired piece (normally the base piece) a computed number of mils. The amount to open or close is determined in the following manner:

- (1) Determine the difference between the width of the desired sheaf and the battery front (with respect to the direction of fire).
- (2) Divide the value determined in (1) above by one less than the number of pieces in the battery.
- (3) Divide the value determined in (2) above by the range in thousands of meters.

b. The sheaf is opened when the width of the desired sheaf is greater than the width of the battery front and closed when the width of the desired sheaf is less than the width of the battery front.

c. No corrections are applied to make the lateral interval between adjacent bursts equal. *Example:* A 105-mm howitzer battery is in position with a battery front 150 meters wide. Fire commands are received which include **BATTERY ADJUST, SHEAF 100 METERS AT 5000**, etc. The executive officer determines the difference (50 meters) between the width of the desired sheaf (100 meters) and the width of the battery front

(150 meters). He divides 50 meters by 5 intervals (6 pieces in the battery). The result (10) is divided by the range in thousands of meters (5.0). The amount to be closed is 2 mils. The fire commands to the howitzers will include DEFLECTION 2639, ON NUMBER 3, CLOSE 2.

d. For an explanation of application of deflection difference by the gunner, see paragraph 83c.

Section IV. FIRE COMMANDS AND THEIR EXECUTION

73. Introduction

a. Fire commands convey all the information necessary for opening, conduct, and cessation of fire. Initial fire commands include all elements necessary for laying, loading, and firing the pieces. Subsequent fire commands include only those elements that are changed, except that the range or quadrant elevation is always announced.

b. The basis for fire commands is the data processed in the fire direction center. These data are received in requests for fire; e.g., from an observer, the FDC of another headquarters, or a supported unit. The fire commands are sent to the battery executive officer by the best available means of communication. The executive officer insures that the howitzer (gun) sections receive and execute the fire commands as prescribed in this manual and unit standing operating procedures.

c. Accuracy in the firing battery is dependent on complete understanding of commands by all personnel. Since numbers make up a large portion of all commands received or given in the firing battery, they must be announced in a clear, precise

72. Axial Observer in High-Burst Registration

The executive officer may act as axial observer for a high-burst registration. His instrument must be placed over a surveyed location (battery center or orienting station) and oriented on a surveyed direction. The precise procedures for an observer in a high-burst registration are set forth in paragraph 224.

manner, in a tempo consistent with the execution of the command, and sufficiently loud to be properly understood. Numbers are announced as follows:

Number	Announced as
0	Zero
1	Wun
2	Too
3	Thuh-ree
4	Fo-wer
5	Fi-yiv
6	Six
7	Seven
8	Ate
9	Niner
44	Fo-wer fo-wer
80	Ate zero
100.7	Wun zero zero point seven
136	Wun thuh-ree six
500	Fi-yiv hun-dred
1478	Wun fo-wer seven ate
7000	Seven thow-zand
16000	Wun six thow-zand

74. Sequence of Command

a. Fire commands are announced to the firing battery in the following sequence:

SEQUENCE			WHEN ANNOUNCED	
No.	Element	Example	Initial fire command	Subsequent fire commands
1	Pieces to follow commands	BATTERY ADJUST	Always	Never.
2	Special instructions	SPECIAL CORRECTIONS or USE GUNNER'S QUADRANT.	When applicable	When applicable.
3	Projectile	SHELL HE	Always	When changed.
4	Ammunition lot	LOT X	When applicable	When changed.
5	Charge	CHARGE 5	Always (except in fixed ammo).	When changed.
6	Fuze	FUZE TIME	Always	When changed.
7	Pieces to fire	CENTER	Always	When either is changed.
8	Method of fire	CENTER 1 ROUND BATTERY 3 ROUNDS IN EFFECT.	Always	
9	Direction	DEFLECTION 2639	Always	When changed.
10	Fuze setting	TIME 18.0	When applicable	When changed.
11	Quadrant elevation	QUADRANT 293	Always	Always.

b. All elements of the fire commands are explained in paragraphs 75 through 85. Some of the elements are used only under special circumstances and are not announced when they have no practical application.

75. Pieces to Follow Commands

The element designating the pieces to follow the commands indicates and alerts those pieces that are to follow commands; this element is always announced in the initial fire command and is not repeated thereafter. A change of the element (all pieces to follow the commands) during a mission constitutes a new mission, and a new series of commands is given. The command consists of two parts: first, designation of pieces to follow the commands and, second, the word ADJUST. Examples of pieces to follow designations are as follows:

a. To alert all pieces, the command is BATTERY ADJUST.

b. To alert base piece, the command is BASE PIECE ADJUST (NUMBER 3 ADJUST).

c. To alert the left (right) (center) pair of pieces, the command is LEFT (RIGHT) (CENTER) ADJUST.

d. To alert any other combination of pieces, the pieces are designated by number; e.g., NUMBER 2, 3, 4, and 5 ADJUST.

76. Special Instructions

The element, special instructions, is used in the cases discussed below.

a. In the rare cases when a particular pattern of bursts is desired, the S3 may direct that special corrections be applied. Special corrections are the sum of position corrections and calibration corrections and are usually computed at the battalion fire direction center. When special corrections are to be used in a mission, the command SPECIAL CORRECTIONS is given as the second element of the initial fire command to alert all personnel that a separate deflection, fuze setting, and quadrant elevation will be announced for each piece throughout the mission.

b. The application of a deflection difference is a rapid method of obtaining a width of sheaf different than the width of a parallel sheaf. When the S3 directs that a deflection difference

be applied, the fire commands from the battalion FDC to the battery FDC will contain, as the second element, the data necessary for the executive officer to compute the deflection difference; namely the desired width of sheaf and the range to the target. An example of such a command is BATTERY ADJUST, SHEAF 100 METERS AT 5000, SHELL HE, etc. The desired width of sheaf and the range to the target is not announced to the pieces. The command to the pieces to apply a deflection difference is part of the element of direction (para. 83).

c. In units in which the pieces are equipped with an on-carriage elevation fire control, the command USE GUNNER'S QUADRANT is announced as the second element of the fire commands in all missions in which the use of gunner's quadrant is desired. In units in which the pieces do not have on-carriage elevation fire control, the gunner's quadrant is used habitually and the command USE GUNNER'S QUADRANT is omitted.

77. Projectile

The type of projectile that will be used to attack the target is always announced in the initial fire command and is not repeated thereafter, unless a change is desired.

78. Ammunition Lot

The element, ammunition lot, indicates the ammunition lot number. Lot number may be announced in the initial fire command and is not repeated thereafter, unless a change is desired. In fixed and semifixed ammunition, the lot number pertains to an assembled projectile—propellant combination and, for simplicity, may be coded as lot X, lot Y, etc. In separate-loading ammunition, when a specific projectile-propellant combination is desired, the lot code may be X-Y, in which X is the projectile lot and Y the propellant lot. Large quantity lots are reserved for registration and subsequent transfers of fire, and the lot number will be announced or prearranged between the FDC and the firing battery. Small quantity lots should be used on battery will-adjust missions. The chiefs of section must segregate ammunition by lot number and keep an accurate record of lots available.

79. Charge

The element, charge, indicates the amount of propellant to be used with other than fixed ammunition. If more than one type of propellant is available, the type (white bag or green bag) to be used is designated by announcing in the initial fire commands the lot of propellant. With ammunition having numbered charges, the command specifies the number of charges to be fired. If the charges are designated as super, normal, or reduced, they are designated as such instead of by numbers.

80. Fuze

A command indicating the type of fuze to be employed is always announced in the initial fire command and is repeated only when changed.

81. Pieces to Fire

a. Any or all of the pieces alerted by the first element of the fire command may be designated to fire. If an adjustment is to be made in area fire, the two center pieces will normally be fired during the adjustment.

b. The element designating the pieces to fire is always announced in the initial fire command but is not announced in the subsequent fire commands unless either the pieces to fire or the method of fire changes. To fire all pieces in the battery the command is BATTERY. To fire any combination of pieces within the battery, the pieces are specified by number or by platoon; e.g., LEFT, CENTER, RIGHT, BASE PIECE, NUMBER 1, NUMBER 2, etc.

82. Method of Fire

There are a number of methods of fire which can be selected depending on the size, shape, and nature of the target; observation conditions; and other considerations. Although the command for each method is distinctive, it generally consists of two parts—the number of rounds to be fired and the method in which these rounds will be fired. The command is always given in the initial fire commands. In subsequent fire commands, the method of fire is announced only when changed or when the number of pieces to fire is changed. In a will-adjust area mission, the method of fire element in the initial fire commands to the adjusting battery will include, in addition to the method of fire to be used in the adjustment, the pieces

to fire for effect, the fuze to be used in fire for effect when other than that used in adjustment, and the method of fire to be used in fire for effect (e.g., CENTER ONE ROUND, BATTERY FOUR ROUNDS VT IN EFFECT, or CENTER ONE ROUND, BATTERY FIVE ROUNDS IN EFFECT).

a. *Volley Fire.* A volley is the firing of rounds from two or more pieces simultaneously. The command for volley fire is (so many) ROUNDS. Unless FDC has sent a command to hold fire (*d* below), the executive will command FIRE when the pieces are ready (fire should not be delayed because of slowness of a portion of the battery). At the command FIRE, all pieces fire their first round. The designated number of subsequent rounds may be fired at the command of the individual chiefs of section as rapidly as possible consistent with accuracy and without regard to the readiness of other pieces. In area fire, the method of fire by the adjusting pieces is usually one volley. The command (so many) ROUNDS AT (so many) SECONDS or (so many) ROUNDS PER MINUTE indicates that single volleys at the time interval specified are to be fired at the executive officer's command. This method may be used to maintain a smoke screen or illumination.

b. *Salvo Fire.* A salvo is the firing of a number of pieces in a definite sequence. The command for salvo fire is RIGHT (LEFT). The designated flank piece (right or left) will fire first, followed at 2-second intervals by each successive piece to the left (right). If a time interval other than 2 seconds is desired, it must be announced as LEFT (RIGHT), AT (so many) SECONDS. If more than one round per piece is to be fired, the command is LEFT (RIGHT), (so many) ROUNDS.

c. *Continuous Fire.* When it is desired to fire continuously at a target, the command is CONTINUOUS FIRE. At this command, the crews will load and fire as rapidly as possible, consistent with accuracy within the prescribed rate of fire for the weapon. The crews will continue to fire until the command CEASE FIRING is given.

d. *At My Command.* AT MY COMMAND may be announced from the FDC immediately after the method of fire is announced. AT MY

COMMAND is part of the method of fire. When the pieces are ready to fire, the executive officer reports BATTERY IS READY to the FDC and fires when he receives the command FIRE from the fire direction center. AT MY COMMAND continues in effect until a new command for method of fire not including AT MY COMMAND is ordered.

e. By Piece At My Command. To fire each piece individually at a time to be controlled from the FDC, the command is BY PIECE AT MY COMMAND. The pieces are fired by number as ordered from the FDC; e.g., NUMBER _____ FIRE. When BY PIECE AT MY COMMAND is in effect, the executive officer will report BATTERY IS READY when all pieces are prepared to fire.

f. Fire At Will. Fire at will is used for direct fire. The command for pieces to fire at will is TARGET (so-and-so), FIRE AT WILL. If a method of close defense has been prearranged, the command is simply FIRE AT WILL. At this command, the designated piece or pieces will fire under the control of the chief of section as the situation and target necessitate.

g. Zone Fire.

- (1) Zone fires are delivered in a constant direction at several ranges (elevation). The normal command for zone fire consists of two parts—the number of volleys to be fired at each quadrant elevation and the zone (in mils). The quadrant elevation, announced as the last element of the fire commands, establishes the center of the zone. The normal command is (so many) ROUNDS, ZONE (so many) MILS. The executive officer has the designated pieces fire the announced number of volleys at the announced quadrant elevation and then the same number of volleys at plus and minus the announced number of mils from the center quadrant elevation (e.g., BATTERY 3 ROUNDS, ZONE 5 MILS). Assuming that the announced quadrant elevation is 240, the executive officer has the battery fire 3 volleys at quadrant elevation 240, 3 volleys at 245, and 3 volleys at 235.

- (2) In some cases, the executive officer may receive the command (so many) ROUNDS, ZONE (so many) MILS, 5 QUADRANTS. The executive officer has the designated pieces fire the designated number of volleys at the announced quadrant elevation and then, in any sequence, at four other quadrant elevations the announced number of mils apart (e.g., BATTERY 2 ROUNDS, ZONE 5 MILS, 5 QUADRANTS). Assuming that the announced quadrant elevation is 190, the executive officer has the battery fire 2 volleys at quadrant elevations 190, 200, 180, 185, and 195.

- (3) The zone command is not transmitted to the weapons. The executive officer controls the battery by announcing the several quadrant elevations.

h. Shifting Fire.

- (1) When the width of the target is too great to be covered with an open sheaf, the target may be attacked by successive shifts.
- (2) Shifting fire is accomplished by laying the battery first on one portion of the target and then successively laying it on the other portions to be covered. Volley fire by battery is delivered alternately on each portion of the target.

i. Do Not Load. When exact firing data or time of firing has not been determined, it may be desirable for the pieces to be laid but not loaded. In such a case, initial fire commands are sent to lay the tubes and the method of fire command includes the command DO NOT LOAD (e.g., 3 ROUNDS, DO NOT LOAD). As soon as the weapons are laid, the executive officer reports (so-and-so) IS LAID. To cause the weapons to fire, a subsequent fire command, which includes a method of fire that does not contain DO NOT LOAD, must be given.

83. Direction

a. To lay the tube for direction, the command is DEFLECTION (so much). This element is always given in the initial fire command but is given in subsequent fire commands only when

changed. The gunner sets off the deflection on his panoramic telescope and then traverses until he is sighted on the proper aiming point. The announced deflection is the sum of the chart deflection and the deflection correction.

b. If special corrections are to be used, the computer at the FDC combines the special correction for deflection, the deflection correction, and the chart deflection, and announces the total deflection for each piece (e.g., DEFLECTION NUMBER 1, 2463; NUMBER 2, 2461; etc.).

c. If a deflection difference is to be applied, the deflection difference is announced as part of the direction element, following the common deflection (e.g., DEFLECTION 2644, ON NUMBER 3, CLOSE 2). The gunner will apply the deflection difference in the proper direction, equal to the number of mils indicated in the command multiplied by the number of pieces his piece is removed from the one on which the sheaf is being opened or closed. For example, the command ON NUMBER 3, CLOSE 3 is given. The gunners will apply the following correction: NUMBER 1, LEFT 6; NUMBER 2, LEFT 3; NUMBER 3, 0; NUMBER 4, RIGHT 3; NUMBER 5, RIGHT 6; NUMBER 6, RIGHT 9. The command for a deflection difference remains in effect until the end of the mission unless a command for another deflection difference is given or the command PARALLEL SHEAF, which cancels the deflection difference, is given.

d. When a unit is equipped with panoramic telescopes that have gunner's aids, the unit commander may choose to use the command CORRECTION (so much), DEFLECTION (so much) to lay for direction. CORRECTION (so much) is the direction and magnitude of the deflection correction and is announced in the initial fire commands only. The correction is applied to the gunner's aid. DEFLECTION (so much) is the announcement of the chart deflection and is always announced in the initial fire commands but is announced in subsequent fire commands only when there is a change from the last announced chart deflection. The deflection correction must always be applied to the gunner's aid before the chart deflection is set off. When special corrections are to be used, the

deflection correction (from deflection correction scale) and the special correction for deflection are combined and the total deflection correction for each piece is announced as CORRECTION, NUMBER 1 LEFT (RIGHT) (so much), etc. prior to the announcement of the common (chart) deflection.

84. Fuze Setting

a. When a time fuze has been specified, a fuze setting will be required in the initial fire commands. This element is announced with the initial fire commands and is reannounced only when changed. The same procedure applies when a fuze setting with variable time fuze is used (e.g., TIME 17.4, TIME 11.9, or TIME 26.0).

b. When special corrections are to be used, the special correction for fuze setting and the common fuze setting are combined by the computer and the total fuze setting for each piece is announced (e.g., TIME, NUMBER 1, 28.4; NUMBER 2, 28.6; etc.).

85. Quadrant Elevation

a. Quadrant elevation is the sum of elevation plus site. The command to lay for quadrant elevation is QUADRANT (so much).

b. When special corrections are to be used, the special correction for elevation is added to the common quadrant elevation and the total quadrant elevation for each piece is announced (e.g., QUADRANT, NUMBER 1, 293; NUMBER 2, 296; etc.).

c. The command for quadrant elevation is the command to load the piece, except when DO NOT LOAD is a part of the method of fire or when a salute is being fired.

d. Unless the method of fire includes BY PIECE AT MY COMMAND, AT MY COMMAND, DO NOT LOAD, or FIRE AT WILL, the command for quadrant elevation received from the FDC gives the executive officer the authority to fire when ready. When all pieces to fire are ready, the executive officer commands FIRE. The chiefs of section should repeat the command FIRE as it is given. The command FIRE should be delayed only when a substantial reason exists, such as safety or accuracy check.

86. Examples of Fire Commands

The commands in *a* and *b* below are applicable to all caliber. All commands are repeated by the executive officer or designated personnel of the firing battery unless otherwise noted.

a. Example of initial command for a precision registration—

BASE PIECE ADJUST
SHELL HE
LOT X
CHARGE 4
FUZE QUICK
BASE PIECE, 1 ROUND
DEFLECTION 2650
QUADRANT 315

b. Example of commands for zone fire—

BATTERY ADJUST
SHELL HE
LOT Y
CHARGE 5
FUZE QUICK
BATTERY 1 ROUND
ZONE 4 MILS
DEFLECTION 2680
QUADRANT 268 (Quadrant elevations 268, 272, and 264 will be fired.)

87. Cease Firing

The command CEASE FIRING, normally, is given by the executive officer but, in an emergency, may be given by anyone present. This command is immediately repeated to the battery by the first individual receiving it. At the command, regardless of its source, firing will cease immediately. If this command originated from the observer or FDC and the piece is loaded, the executive officer reports NUMBER 2 (or other piece) LOADED. If firing is stopped by someone at the position, the executive officer reports that fact and the reason therefor to the fire direction center. Firing is resumed at the announcement of quadrant elevation.

88. End of Mission

The command END OF MISSION means that the fire mission has been completed.

89. Repetition of Commands

a. By Chief of Section.

(1) *Voice communication.* Chiefs of section repeat the commands FIRE and CEASE FIRING. Any other commands given by the executive officer are repeated only when requested or when they obviously have not been heard or understood. The request for repetition is a question (e.g., DEFLECTION NUMBER (so-and-so) ?; QUADRANT NUMBER (so-and-so) ?).

(2) *Intrabattery communication.* When wire communication is used between the executive officer's command post and the individual sections, the read-back of elements of the fire commands will be governed by unit standing operating procedure. The cannoneer operating the telephone must announce each element of the fire commands to his section.

b. By Executive Officer. The repetition of commands by the executive officer or the person transmitting commands to the pieces is always preceded by THE COMMAND WAS (e.g., THE COMMAND WAS, DEFLECTION 2768).

90. Signals

Arm and hand signals are used in conjunction with oral commands to achieve greater clarity. A chief of section extends his right arm vertically, with palm of hand toward the executive officer (the *ready* position), to indicate that his piece is ready to fire. When he cannot be seen by the executive officer, he reports orally NUMBER (so-and-so) READY. The commands FIRE and CEASE FIRING usually are given by arm signals as well as by voice. The signal for FIRE is either to drop the right arm sharply from the *ready* position to the side or to point with the right hand at the piece to be fired, extend the arm to the *ready* position and drop it sharply to the side. The signal for CEASE FIRING is to raise the hand in front of the forehead, palm to the front, and swing hand and forearm up and down in front of the face. Another signal for CEASE FIRING is one long blast on a whistle.

91. Barrages

a. The battery barrage is designed to be fired quickly on a critical line. It is a high priority fire, taking precedence over all other fire missions. When the battery is not firing other missions, it is laid on its barrage and appropriately prepared rounds are kept at the pieces.

b. The barrage may be initiated by the command BARRAGE or by a prearranged signal. When personnel are resting, the piece sentinels begin firing immediately on the command BARRAGE or on receipt of the prearranged signal.

92. Reports

The executive officer reports to the FDC all actions that affect the firing of the battery. In addition to those reports previously mentioned (BATTERY IS READY, BATTERY IS LAID, CEASE FIRING), the following specific reports are made:

a. ON THE WAY (NR 1 ON THE WAY)—when a first round of salvo, volley, zone, or other series of fire has been fired. This report is preceded by the piece that is firing only when information is necessary for coordination (e.g., BY PIECE AT MY COMMAND).

b. ROUNDS COMPLETE—when the final round of fire for effect (other than one volley) has been fired.

c. MISFIRE NUMBER (so-an-so)—when there has been a misfire. NUMBER (so-and-so) IS READY—when again ready to fire, if fire mission has not been completed.

d. NUMBER (so-and-so) IS OUT (reason)—when a piece has been called out.

e. Number of rounds expended, by type (and lot number when required)—at the completion of each fire mission.

f. Chiefs of section must report immediately to the executive officer all errors that have caused a round to be fired with improper data. The executive officer has these errors corrected and reports to the FDC (e.g., NUMBER 2 FIRED 20 MILS RIGHT: ERROR HAS BEEN CORRECTED).

93. Checking Settings During Firing

The executive officer usually checks settings and laying during lulls in firing. When the executive officer questions the accuracy of the laying of any piece, he calls that piece out, reports to the FDC, and has the necessary checks made. When the battery is firing close to friendly troops, frequent checks must be made to insure safety.

94. Correcting Fire Commands by Executive Officer

a. If an incorrect element has been announced but FIRE has not been given, the correct element preceded by CORRECTION, is given, followed by all subsequent elements.

b. If FIRE has been given, the executive officer announces CEASE FIRING. He then gives the proper element followed by all subsequent elements and repeats the command FIRE.

Section V. ASSAULT FIRE

95. Introduction

a. Assault fire is a special technique of indirect fire. Fire is conducted at a relatively short range to attain pinpoint accuracy against a stationary target. The gun-target range is sufficiently short to make possible successive hits on the same portion of the target. Only one piece is used on a mission, and the FDC for the mission is normally located at the gun (howitzer) position. Thorough planning, reconnaissance, and coordination must be completed before the gun (howitzer) position is occupied.

b. Any artillery cannon can be used for assault fire; however, any caliber smaller than

155-mm is considered uneconomical. The most efficient weapons, in order of preference, are the 8-inch howitzer and the 155-mm howitzer. Self-propelled versions of these weapons are best suited in many instances for this task because of their maneuverability and ease of emplacement and displacement. When the maximum charge is used, maximum effective assault fire ranges are 3,000 meters for the 8-inch howitzer and 2,500 meters for the 155-mm howitzer.

96. Procedure

a. In order to make the small deflection changes which are necessary in assault fire, a

special technique of laying is employed at the piece. Deflection changes are made to the nearest mil until a 1-mil deflection bracket is obtained; further changes are made to the nearest one-fourth mil. A deflection board attached to an aiming post is used for this purpose. The deflection board illustrated in figure 31 enables

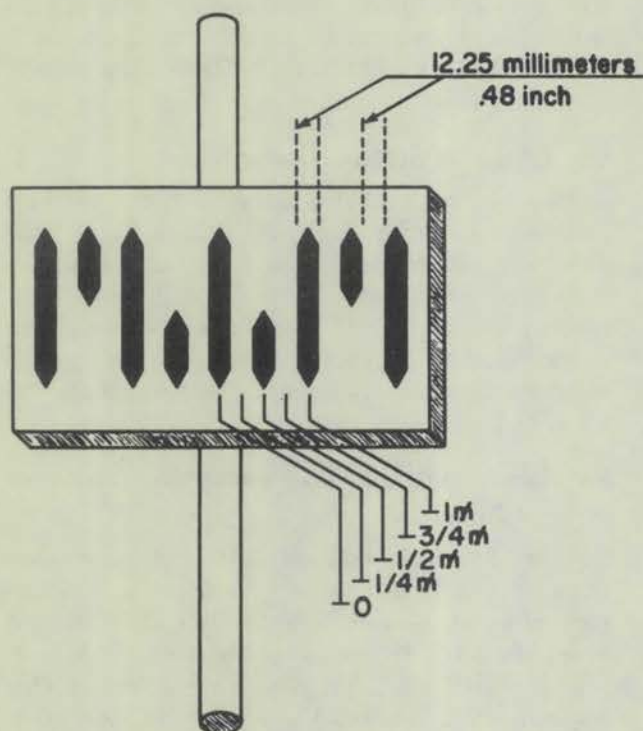


Figure 31. Deflection board.

the gunner to make deflection changes of one-fourth mil. The black and white bands (lines) are one-fourth mil in width when viewed through the sight of the piece at a distance of *exactly* 50 meters. The gunner lays on the desired portion of the board by centering the vertical crosshair of the sight upon a black (white) band on the board. To move one-fourth mil, he moves the line of sight, by traversing the piece in the proper direction, so that the adjacent white (black) band is covered; to move one-half mil, the vertical crosshair is moved two bands, etc.

b. Changes in elevation are made to the nearest 0.1 mil; the gunner's quadrant is used.

97. Direct Fire

Firing by direct laying is a special technique that demands a high standard of training. The section must operate as an independent unit. Enemy targets taken under fire by direct laying procedures are usually those capable of returning fire at pointblank range; therefore, the speed and accuracy required in direct fire are of the utmost importance.

a. Methods of Sighting.

- (1) *Two-man, two-sight.* Using the two-man, two-sight system, the gunner establishes lead with the panoramic telescope and the assistant gunner establishes elevation with the direct fire telescope. This system is the fastest and most accurate and permits the assistant gunner to check the direction of lead.
- (2) *Two-man, one-sight.* Using two-man one-sight system, the gunner establishes lead with the panoramic telescope and the number 1 man sets elevation on the elevation quadrant at the command of the chief of section. This system is most effective when the target is moving on flat terrain.
- (3) *One-man, one-sight.* Using the one-man, one-sight system, the gunner lays for lead and elevation with the reticle of the panoramic telescope. This system should not be used if the target is moving on a steep slope.

b. Methods of Laying.

- (1) *Click sights.* A modification on the micrometer knob of the panoramic telescope permits the gunner to set off lead in 5-mil increments, by sound or feel, without removing his eye from the sight.
- (2) *Reticle laying with deflection zero.* The gunner maintains lead by placing the vertical hairline the proper number of mils ahead of the center of the target.
- (3) *Central laying.* The gunner sets the lead in mils on the azimuth micrometer scale of the panoramic telescope and maintains the vertical hairline of the reticle on the center of the target.

- (4) *Continuous tracking.* Lead and elevation are laid and maintained in following the target.
- (5) *Laying ahead.* The gunner does not track the target but lays ahead of it for lead and adjusts the elevation as the target approaches the correct lead.

c. *Canted Reticle.* A canted reticle in the

elbow telescope prevents satisfactory direct fire on moving targets. An unacceptable range error is introduced when lead is changed.

d. *Direct Fire Characteristics.* The direct fire characteristics of current standard field artillery weapons vary widely. For a discussion of a particular weapon, see the field manual for the weapon involved.

CHAPTER 5

FIRING BATTERY OPERATIONS AND TRAINING

Section I. GENERAL

98. Introduction

Field artillery doctrine demands the delivery of timely and accurate fires. The firing battery, as part of the gunnery team, bears a large share of the responsibility for the delivery of effective fire. The battery executive officer is in direct charge of the training and operation of the firing battery. During training he must institute practices and procedures which will assure the accurate and timely execution of fire commands.

99. Principles of Training

a. Proper training of the firing battery starts with training of each individual in the specific duties in service of the piece prescribed in the appropriate manual. Next is the training of the section as a team. Finally, the sections are brought together and trained as the firing battery. Standing operating procedures must be developed as training progresses.

b. In the initial stages of each phase of training accuracy must be emphasized. As training progresses speed is gradually gained, but loss of accuracy is not tolerated.

c. The firing battery must be trained to occupy position and execute fire commands faultlessly at night.

100. Conduct of Service of the Piece Drill

a. Successful operation of the firing battery depends primarily on instilling, in each man, pride in the rapid and precise execution of his duties. The success of service of the piece drill depends on the ability of the chiefs of section and the executive officer and his assistants to recognize unsafe, incorrect, inaccurate, or careless performance of duties by individuals. Service of the piece drills provide practice and test the whole team as well as the individual members. Pieces should be placed close together to facilitate observation and supervision. Tele-

phone communications may be installed to train section personnel in use of telephones for receipt of commands and to simulate firing conditions. The chief of section may operate the section telephone or he may designate a high-numbered cannoneer as telephone operator. If the chief of section operates the section telephone, he must not permit this duty to affect his primary responsibility for his section. He cannot merely operate the telephone and repeat commands; he must retain freedom of movement, must continuously supervise his sections, and must insist on the highest possible standards. Deficiencies in the training of individuals must be noted and corrected on the spot.

b. Drills should be kept interesting, short, and snappy, with frequent rests. The gunner and all cannoneers may exchange positions after personnel have gained full proficiency in their own jobs. The executive officer frequently should time the sections with a stop watch to emphasize speed as well as accuracy. Although the scheduled training time normally will be at least 1 hour, the time should be broken into separate phases. For example, a drill period may consist of 10 minutes to prepare for action and laying; 45 minutes for service of the piece drill, with rests between problems, broken into section drill and battery drill; and 5 minutes for march order. During the drill, checks of settings and laying for accuracy and correctness must be made frequently and without notice by chiefs of section, chief of firing battery, assistant executive officer, and executive officer. Several times during the drill, when all pieces are ready to fire, the command to fall in at the rear of the pieces should be given, and, with the sections at rest, the laying and settings in each section should be verified by the chief of section. Planning will enable specific individuals to observe and check specific items, and the use of command cards will speed and improve the conduct of the drill. Occasionally, the

chiefs of section should be drilled separately in the setting of the gunner's quadrant. This drill should not exceed 5 minutes' duration and should include settings to the nearest 0.1 mil.

c. *Fire command cards prepared in advance* are used during all drill periods. The cards should contain complete sets of fire commands. The battery must be trained to execute all possible fire commands. Large changes in deflection and elevation (greater than 100 mils) should be included in some commands to facilitate checking for 100-mil errors. Changes in deflection that require shifting of trails should be avoided except when training is being conducted in trail shifting. The method of fire should be changed frequently to teach the various methods of fire, to increase alertness, and to insure familiarity with all commands so that no command during firing will surprise any member of the firing battery. As training progresses, more difficult commands should be included and more difficult situations presented. Fire command cards must be changed occasionally to insure that commands are not memorized.

101. Accuracy Requirements

Some of the standards which must be met during all service of the piece training (firing or drill) are listed below.

a. *Bubbles.* After the breech is closed and prior to firing, the bubbles must be centered exactly.

b. *Indexes.* The proper graduation must be aligned exactly with the index.

c. *Micrometer Knobs.* In setting scales with the micrometer knobs, the last motion must be from the lower to the higher reading.

d. *Traverse.* The last motion of the traversing handwheel should cause the vertical hairline of the panoramic telescope to approach the aiming posts or aiming point from left to right. If the vertical hairline passes the aiming point, the handwheel should be turned back one complete turn and a new approach made. The gunner must be trained to habitually lay with the right edge of the vertical hairline on exactly the same portion of the aiming point (left edge on aiming posts when exactly vertical). He must then insure that both bubbles are centered.

e. *Fuze Setters and Fuzes.* Settings on the fuze setter should be made with the last motion in the direction of increasing readings.

f. *Elevation.* In elevating or depressing the tube of any field artillery piece, the last motion of the handwheel should be in the direction which offers the greatest resistance. If the bubble level point is passed, the handwheel should be turned back one complete turn before centering the bubble.

g. *Aiming Posts.* The far aiming post should be approximately 100 meters from the sight of the piece. The near aiming post must be exactly one-half the distance to the far aiming post. The chief of section and the gunner must check to insure that aiming posts are placed at the proper distances and are exactly vertical and aligned.

h. *Uniformity in Ramming.* Uniform ramming helps prevent unusual variations in muzzle velocity. Nonuniform ramming may cause variations in seating, escape of propellant gases around the projectile, and variation in the effective size of the powder chamber. These factors will in turn cause range inaccuracies. Hard ramming is essential to safety. If the projectile is not seated firmly, particularly at high quadrant elevations, it may slip back into the powder chamber and rest on the charge. If the weapon is fired with the projectile in this position, premature detonation may occur, causing a serious accident.

102. Equipment Checks

a. All fire control equipment must be in correct adjustment. All section equipment, especially sighting and laying equipment, should be checked frequently for serviceability and completeness. Sighting and laying equipment should be checked immediately after the battery goes into firing position. Some tests and adjustments are made periodically or when the need is evident. Only those adjustments authorized in the technical manual for the weapon may be made by battery personnel.

b. *Boresighting* is the process by which the optical axes of the panoramic and elbow telescopes are made parallel (vertically and horizontally) to the axis of the bore, with the scales of the mounts and telescopes set at zero. (See specific weapon field manual for methods of boresighting.)

Section II. FIELD OPERATION OF FIRING BATTERY

103. Duties of the Battery Executive Officer

The duties of the battery executive officer are as follows:

a. Prior to leaving the motor park or assembly area, he—

- (1) Insures that personnel check tire pressures, recoil mechanisms, boresighting, adjustment of instruments, and equipment and ammunition for completeness, serviceability, and proper storage.
- (2) Makes a reconnaissance of the new position, if feasible, and determines zone of fire or safety limits.

b. At the firing position, he—

- (1) Supervises occupation of position.
- (2) Verifies the laying of the battery.
- (3) Checks communications.
- (4) Has personnel recheck recoil mechanisms and adjustment of instruments.
- (5) Determines minimum quadrant elevations.
- (6) Gives executive officer's report to the FDC.
- (7) Has the pieces boresighted, if time permits.
- (8) Controls the delivery of fire as requested by the observer when mission is being conducted by battery or as commanded from the FDC when mission is being conducted by battalion.
- (9) Is responsible for compliance with safety rules.
- (10) Insures uniform and adequate storage of ammunition.
- (11) Supervises accounting of ammunition to include lot segregation and control.
- (12) Supervises fire direction at the battery.

c. Prior to entering combat (actual or simulated), he insures that the firing battery is capable of—

- (1) Twenty-four hour operation.
- (2) Efficient occupation and organization of the position.
- (3) Passive defense of the position through proper camouflage discipline and other measures.
- (4) Active defense of the position by di-

rect laying of the pieces, by use of other organic weapons (machineguns, rocket launchers, and small arms) and by use of mines and trip flares.

- (5) Operating efficiently within safety rules.

104. Duties of the Recorder

a. The recorder is an assistant to the battery executive officer and is a member of the battery fire direction center. As his title implies, he maintains certain records for the executive officer. Among those records are—

- (1) DA Form 6-17 (Firing Battery Recorder's Sheet) on which he records laying data, fire commands, and a running total, by type and lot, of ammunition on hand in each section (fig. 32).
- (2) File of prearranged fires to include the barrage data.
- (3) Record of minimum quadrant elevations and referred deflections for each weapon.

b. When directed, the recorder announces fire commands to the pieces.

105. Records and Data Maintained in the Firing Battery

In addition to the recorder's sheet (para. 104), the following records are also kept in the firing battery and must be checked by the executive officer for completeness and accuracy:

a. Firing battery section data sheets (DA Form 6-13) (fig. 33) are usually prepared by FDC for prearranged and close-in defensive fires. Section data sheets contain the information necessary to permit the chief of section to fire the listed concentrations. The chiefs of section are responsible for announcing the fire commands directed on the section data sheet.

b. The U.S. Equipment Log Book is for recording the history of the carriage or mount and the tube data. DA Form 2408-4 (1 Apr 62) of the U.S. Equipment Log Book serves as a permanent life history of a weapon and must be checked periodically, especially calibration data and ordnance service entries. Maintenance records kept by the artillery mechanic must be current to supplement data in the U.S. Equipment Log Book.

FIRING BATTERY RECORDER'S SHEET										Battery B		Date 1 JUL 64		Page number 1									
Battery laid on										Ammunition on hand													
Azimuth 1600		Orienting angle 735		Deflection 2800						MS7		MS20		MS13		WP							
Fire commands										Individual piece correction						400		300		100		50	
Pieces to follow	Sp Corr	Sh	Lot	Chg	Fz	Pieces to fire/MF	Df	Ti	El or QE	Piece	Df	Ti	QE	Ammunition expended									
BA		HE	X	5	Q	C ①								2									
						B ②								4									
						B ③								(16)									
END OF MISSION CONC										AD 417				384	300	100	50						
BA	✓	HE	Y	6	TI	B ③	AMC	#1	2748	14.8	228												
								#2	2750	14.8	229												
								#3	2751	14.9	231												
								#4	2753	14.9	232												
								#5	2754	14.8	228												
								#6	2755	14.8	227												
END OF MISSION CONC										AD 419				384	282	100	50						

DA FORM 6-17
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 32. Firing battery recorder's sheet.

FIRING BATTERY SECTION DATA SHEET (FM 6-40)								SECTION 1		BATTERY B		DATE 13 MARCH		PAGE NO. 1	
CONC. NO.	TIME		SH.	AMMUNITION			METHOD OF FIRE	CORR	DF	TIME	QE.	REMARKS			
	FROM	TO		LOT	CHG	FZ.									
AB 403	0515	0519	HE	X	5	TI	B(3)		2762	16.5	260				
AB 405	0522	0524	HE	X	5	Q	B(2)		2661		236				
AB 412	0525	0527	HE	X	5	VT	B(4)		2581	14.0	221 218 215	ZONE 3 1/4			
AB 410	0528	0530	HE	X	5	Q	B(4)		2918		338				
BARRAGE	ON CALL		HE	X	4	Q	CONT. FIRE.	#1	2714		217				
								#2	2716		216				
								#3	2713		217				
								#4	2715		213				
								#5	2717		215				
								#6	2716		218				

DA FORM 6-13
1 DEC 63REPLACES DA FORM 6-13, 1 MAR 57, EXISTING SUPPLIES OF WHICH WILL BE
ISSUED AND USED UNTIL 1 DECEMBER 1964 UNLESS SOONER EXHAUSTED.

GPO 805-853

Figure 33. Firing battery section data sheet.

weapon record book serves as a permanent life history of a weapon and must accurately reflect the ammunition fired and the date of firing. Entries must be checked periodically, especially

calibration data and ordnance service entries. Maintenance records kept by the artillery mechanic must be current to supplement data in the weapon record book.

Section III. CARE AND HANDLING OF AMMUNITION

106. Ammunition References

The technical manual issued with each weapon lists the authorized ammunition and the marking, packing, and other technical information. For a general discussion of ammunition, see TM 9-1900; for characteristics of all types of artillery ammunition, see TM 9-1300-203.

107. General Safety Precautions

a. Careful handling of ammunition is necessary to insure proper functioning and to avoid accidents. Since accuracy of fire is affected by damaged ammunition, the care and handling of artillery ammunition must be carefully supervised. Firing battery personnel must have a detailed knowledge of the marking, purpose, and functioning of each component.

b. Basic principles of ammunition handling for firing battery personnel are as follows:

- (1) Know in detail how to assemble and prepare the ammunition.
- (2) Never use bale hooks. Do not tumble, drag, throw, or drop boxes or components.
- (3) Do not allow smoking, open flames, or other fire hazards around ammunition.
- (4) Keep ammunition in sealed containers as long as possible. Return ammunition to containers and reseal if not used.
- (5) Check and list lot numbers of projectiles, fuzes, propellants, and primers.
- (6) Inspect each round prior to use to insure that it is clean, properly assembled, and otherwise suitable for use.
- (7) Protect all components from moisture, extremes of temperature, and corrosive chemicals.
- (8) Never make unauthorized alterations on the ammunition.

108. Projectiles

a. Projectiles must be inspected to insure that there is no leakage of the contents, that they are correctly assembled, and that bourrelets and rotating bands are smooth and free of burrs and large dents. If rotating bands are burred or nicked, they should be smoothed with a flat, fine-grained file or with crocus cloth backed with a small block of wood. Projectiles, especially those without the fuze and booster assembled, are relatively safe from detonation by small arms fire or shell fragments. Lifting plugs on separate-loading ammunition should be kept tight in the shell nose until the projectile is ready for use, to prevent moisture from affecting the explosive and to prevent rust from freezing the lifting plug in place. Rotating band grommets must be secure and tight to prevent nicking and scarring the comparatively soft rotating bands. Windshields must be tightened flush with the shell body and locked by the setscrews. Care must be taken that the false ogive is not broken loose from the threaded ring by which it is attached to the shell body.

b. High explosive shells issued for use with VT fuzes are standard shells with the fuze and booster cavities deepened to accommodate the longer VT fuze. These deep cavity shells are issued with a removable supplementary charge so that they may be used with either standard time or impact fuzes or with VT fuzes. With the supplementary charge placed in the deep cavity, shells are packed, shipped, and issued in the usual manner—fixed or semifixed rounds fuzed with standard time or impact fuzes (sometimes with no fuze) and separate-loading shells closed with a cardboard spacer and the usual eyebolt lifting plug. The supplementary charge is removed only when the shell is used with VT fuzes and must be in place when used with standard time or impact fuzes. The deep cavity may be lined with a paper tube and bot-

tom cup which helps support the high explosive filler. This lining will not be removed at any time.

109. Propelling Charges

a. Care must be exercised to insure that all increments of propelling charges are present and of the same lot number and that only the proper increments are removed from the complete charge before firing. The cannoneer preparing propelling charges for firing must count and identify by number not only the increments removed from a charge as it is to be fired but also the increments not removed. This precaution will help eliminate mistakes in the preparation of the charges and will also detect missing or duplicate increments. Powder bags should not be torn or ripped, and there should be no leakage of contents. With separate-loading ammunition, the data tag and igniter pad cover must be removed before the charge is loaded. Ammunition which has been prepared for a certain charge should be carefully segregated from other ammunition. Charges for which firing is not immediately planned should be resealed. Increments removed from a prepared charge are left with the charge until the charge is fired so that, if necessary, higher charges than originally planned may be fired or ammunition repacked conveniently. Increments left over from charges already fired are immediately removed to a point 30 to 40 feet from the nearest weapon or ammunition until the battery personnel can dispose of them.

b. It is not practical to salvage unused increments. Unused increments may be burned in the open in small quantities. If large quantities are ignited, a dangerous explosion may result. When it is necessary to destroy igniter pads, they should be separated from the base charge and handled in accordance with the provisions of TM 9-1900. Igniter pads should never be cut open with a metallic object, such as a knife, for premature ignition may result.

c. Propelling charges absorb moisture and should be kept in the containers until just before use. This precaution reduces the danger of fire from sparks, blowbacks, small-arms fire, and hot shell fragments. Propellants must also be protected from excessive and rapid changes

in temperature and the direct rays of the sun. High temperatures greatly accelerate the normal rate of deterioration and cause excessive and irregular chamber pressures in firing, resulting in erratic ranges. Sudden changes in temperature may also cause moisture to condense on the charges. At the battery position, the powder temperature of ready ammunition (powder charges) that is representative of ammunition due for early use should be checked periodically. The rounds or powder charges so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean. The thermometer should penetrate the charge that is being used, and it must not touch any metal.

110. Cartridge Cases

Cartridge cases should be inspected carefully for cracks or dents which might affect their functioning. Care is necessary in handling cartridge cases, for they are easily dented. Care must be taken to protect the bases of cartridge cases, which, if struck, may cause accidental firing of the primer. Badly corroded cartridge cases are difficult to extract from the chamber and may rupture. With semifixed ammunition, it is important that the mouth of the case is not deformed. A deformed case is difficult to load and may result in a serious blowback if fired.

111. Fuzes

a. Fuzes are sensitive to shock. Their functioning is likely to be impaired by moisture or high temperature. Fuzes should be inspected carefully to ascertain that they are properly assembled and set. Separate fuzes should be tightened as much as possible by hand and then firmly seated with a fuze wrench. Care must be taken to start the mesh of the threads properly. When fuzes are not tightly seated, premature detonation may occur through sudden seating from rotation in the bore. With fixed and semifixed ammunition, the packing stop must be removed before firing.

b. To prevent excessive cutting of mechanical time and variable time fuzes which may cause malfunction of the fuzes, fuze settings for nonadjusting pieces in a well-adjust mis-

sion, or a mission prefaced by "do not load" (DNL), will be set on the fuze setters only. The fuze setter is set at the time announced, but the fuze is not cut until the command to fire the round is received. This will preclude setting the fuze more than once if a different fuze setting is required when the final time is announced. Time fuzes which have been cut but not fired are reset to SAFE, and the safety pin is inserted before replacing fuzes in the containers.

c. For accurate and rapid setting, time fuzes require a fuze setter graduated to suit the fuze. A number of models of fuze setters have been standardized. The details of the use of fuze setters are contained in the appropriate field manual for the weapon.

d. Variable time fuzes (fig. 34) belong to a class of special fuzes that require specially loaded projectiles. The length of the fuze booster assembly is longer than that of standard impact fuzes. The ogives of some of the fuzes have a heavy coating of wax that must not be removed. The fuzes are completely bore and muzzle safe. The arming mechanism of the M513- and M514-series fuzes provides an additional safe period during the first 2 seconds' time of flight. Fuze settings are made manually with a mechanical fuze setter. It is important that the time scale of the fuze setter correspond to the time ring of the fuze (0-100 with fuzes M513 and M514, all modifications). Fuze settings for mechanical time and variable time fuzes are made in the same manner; the individual setting the fuze should look down on the nose of the fuze and rotate the cap in a clockwise direction which is the direction of increasing readings. In the event the fuze setter M14 or M27 is used and the desired setting is passed, the clockwise rotation of the cap is continued until the desired setting is again reached. The cap should not be "backed up" to the setting because this introduces backlash and reduces timing accuracy. The arming delay time should not be set more than twice on any fuze. The zero setting line is the lowest point at which VT action can be expected from the fuze. The ammunition caliber is stenciled on the fuze body. For details on the care and use of fuzes,

refer to appropriate ordnance technical publications.

112. Primers

Primers are sensitive to shock and moisture. Primers should be carefully cleaned and inspected for signs of corrosion and to insure that the seal is firmly in place. Primers will be kept away from powder bags and left in their sealed containers until ready for use.

113. Flash Reducers

The strips containing flash reducing chemicals should be tied tightly and smoothly to the propelling charge so that the diameter of the whole charge is equal throughout its length. Because of its hygroscopic qualities, the flash reducer must not be removed from the container until just before it is to be used. The flash reducer must not be allowed to contact damp ground. Discarded increments should be disposed of in the same manner as discarded igniter pads (para. 109b).

114. Chemical Shells

a. When toxic chemicals are being fired, all personnel should wear protective masks and personnel handling the ammunition should wear gloves. Decontaminating agents should be held in readiness.

b. White Phosphorus (WP) shells will be stacked vertically and protected from high temperatures. If WP shells are stacked horizontally in the hot sun, the WP filler (melting point 110° F.) may shift to one side of the shell cavity, resulting in an unbalanced projectile.

115. Segregation of Ammunition Lots

Different ammunition lots have different ballistic qualities. Registration corrections derived from firing one lot of ammunition are not necessarily valid for another lot; therefore, it is necessary to segregate the ammunition in the position area by lot. Proper segregation requires control and accounting by the chiefs of section, recorder, and battalion fire direction center. Each stack of ammunition should have the lot number (or a unit code designation for that number) prominently displayed. As a general rule, the firing of the lot used for a

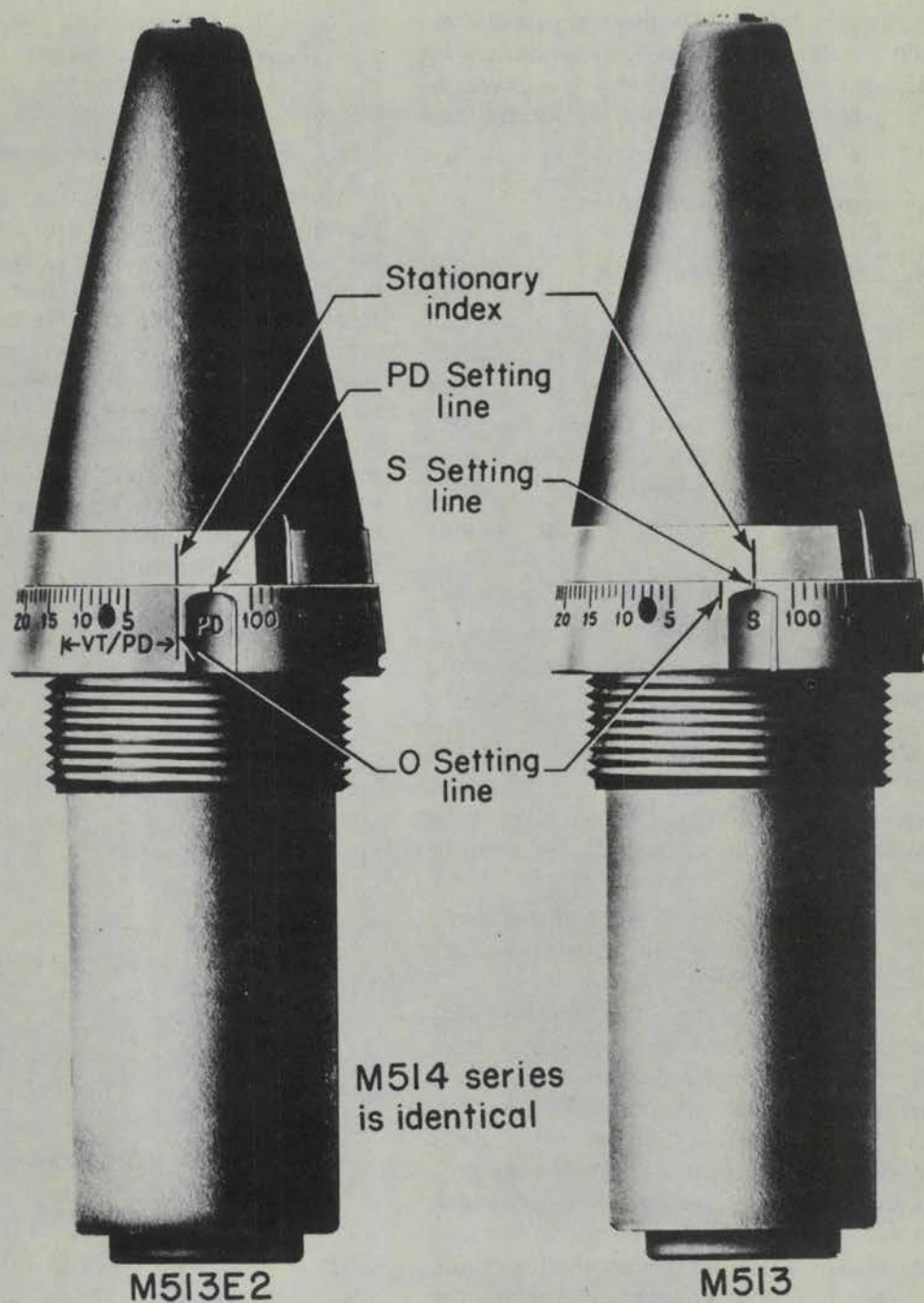


Figure 34. Variable time fuzes M513 and M513E2.

registration is restricted to transfers and missions in which two or more batteries are to mass. In units which fire separate-loading ammunition, both propellants and projectiles must be segregated by lot, and the desired propellant-projectile combination must be designated in the initial fire command. When fixed or semi-fixed ammunition is used, only the lot for the complete round is announced.

116. Replacing Ammunition in Containers

Great care must be exercised in returning ammunition to containers to insure that it is completely serviceable. Before a round is replaced in its container, an officer of the battery will prepare a certificate, which is inserted under the sealing tape used to seal the container so that it will be visible, certifying that—

- a. All increments are present.
- b. Increments are serviceable and undamaged.
- c. Increments are in proper numerical order.
- d. Increments have the same lot number.
- e. Lot number of the ammunition is the same as that on container.

117. Data for Computation of Corrections

The executive officer supplies the FDC with the following ammunition data for computing corrections:

a. *Weight of Projectile.* Weight of projectile is reported as marked on the projectiles; e.g., 1 square, 2 square, (number) pounds.

b. *Powder Temperature.* The powder temperature reported should be a representative figure for the charges to be fired by the battery, considering variations within stacks and differences between sections. The method of using the powder thermometer will vary with the type of ammunition. Powder temperatures are taken as follows:

- (1) *Separate loading.* Insert the thermometer in end of charge and replace the charge in container.
- (2) *Semifixed.* The charge, with thermometer inserted, is replaced in cartridge case.

- (3) *Fixed.* With fixed ammunition, there is a temperature lag between the inside and outside of the cartridge case. Powder temperature can be approximated by placing the cased thermometer inside an empty ammunition container.

118. Field Storage of Ammunition

Ammunition at the battery position must be protected from enemy fire and the weather. Only enough ammunition to meet current needs is placed at the pieces. Other ammunition is stored either on the prime movers, on the ammunition vehicles, or, when especially authorized, at a battery dump. Establishment of a battery ammunition dump is a matter for command decision, because a dump impairs the mobility of the battery. Proper cover reduces the risk of damage by enemy fire and also serves to protect ammunition from moisture and extremes of temperature.

119. Unloading the Piece

When practicable, a loaded piece should be fired rather than unloaded. However, troops should be instructed in the proper method of unloading. They should be assured that if the pieces are not overheated and proper procedures are followed, unloading can be accomplished safely. Details on unloading are contained in the appropriate field manual for the weapon.

120. Accidents

AR 700-1300-8 prescribes the method for reporting a premature explosion or other ammunition accidents. The officer in charge at the battery position must—

- a. Render first aid to those injured.
- b. Notify immediate superior.
- c. Obtain statements from eyewitnesses while details are clearly in mind.
- d. Preserve all evidence in as nearly the original state as possible until it can be inspected by the ordnance officer.
- e. Record all data required by AR 700-1300-8.

Section IV. COMMON MISTAKES AND MALPRACTICES

121. General

Inaccuracies and waste in artillery fire too often occur from mistakes and malpractices of a recurring nature. A mistake is an unintentional error in action or perception committed while following correct procedure. A mistake usually indicates carelessness or lack of concentration and can be detected only by a positive, independent check or very close supervision. A malpractice is a procedural error and usually indicates incomplete or incorrect training. The best preventive for mistakes and malpractices is the formation of proper habits in training by insisting on exactness and allowing no deviation from correct procedures. A further preventive for errors is to establish in training proper supervisory procedures for the executive officer, chief of firing battery, and chiefs of section so that all errors are detected and corrected prior to firing. This section is a tabulation of some of the more common firing battery errors.

122. Preparation for Firing and Execution of Fire Commands

a. Common Mistakes. Some of the common mistakes made by personnel of the firing battery in executing fire commands are—

- (1) Firing wrong charge.
- (2) Missetting fuze, especially by reading in wrong direction from numbered graduation.
- (3) Making a 100-mil error in deflection or quadrant elevation.
- (4) Moving in wrong direction from numbered graduations on micrometer scales.
- (5) Reading wrong colored figures on 10-mil micrometer of gunner's quadrant.
- (6) Leveling gunner's quadrant in wrong direction or using wrong base, especially in high-angle fire.
- (7) Laying on wrong aiming posts, especially at night or when there is little lateral interval between pieces.
- (8) Failing to take up lost motion correctly.
- (9) Failing to center all bubbles.

b. Malpractices. Malpractices which may result in serious accidents are—

- (1) Attaching lanyards on 105-mm howitzers directly to the trigger shaft rather than to the firing shaft bracket assembly. This permits firing the weapon before it has returned to battery. The result is damage to the recoil mechanism and carriage and possible injury to the loader from the recoil.
- (2) Inserting the trigger shaft to test the functioning of the M13 firing lock of the 105-mm howitzer. This practice breaks the lugs forming the "T" on the end of the firing pin holder.
- (3) Attempting to gain greater ranges by firing propellant charges other than those authorized by firing tables. This results in excessive heat and chamber pressures which cause metal fatigue.
- (4) Loading of the 155-mm howitzer without using the tray may result in burred breech threads, damaged rotating bands, and improper seating. Erratic fires result.
- (5) Removing the safety latch firing mechanism plunger so that the firing mechanism and primer can be inserted prior to closing the breech. This practice may result in blown breechblocks and housings.
- (6) Exceeding the maximum rates of fire thus causing the gun tubes to become extremely hot. Shells, cool from having been stored in the open, may crack when placed in the hot gun tubes, permitting the filler to melt and run out of the cracks into the powder chamber making an explosion likely. If fired, the broken shell endangers friendly troops. When the maximum rate of fire is exceeded, the recoil mechanism also becomes extremely hot. This causes a marked increase in pressure within the recoil system which may, in turn, damage the system.
- (7) Digging gun pits in such a manner

that the bottom of the pit slopes upward toward the rear. A weapon emplaced in such a pit will be tilted forward. This will reduce the maximum elevation attainable and may restrict firing high-angle fire.

123. Aiming Circle

Some of the errors made by the firing battery personnel in using the aiming circle are—

- a. Failing to clamp vertical shaft securely (M1 only).
- b. Failing to clamp the wingnut (lower fast motion) securely.
- c. Turning sight head with the wrong motion when sighting through the eyepiece; i.e., upper motion instead of lower motion.
- d. Failing to level the longitudinal bubble before reading angles of site.
- e. Failing to determine and apply the vertical angle correction to measured angles of site.
- f. Having objects containing magnetic metals on the person, especially eyeglasses.

g. Making a 100-mil error in setting by failing to note that turning the azimuth micrometer has moved the azimuth index to the wrong hundred or setting; for example, 3,697 instead of 3,597 because the azimuth index is near 36.

h. Failing to take up lost motion correctly.

i. Failing to set up instrument with one leg pointing in the approximate direction of sighting.

j. Failing to set up instrument at least 40 meters from nearest piece.

124. Miscellaneous

Some of the miscellaneous errors made by the firing battery personnel are—

- a. Failure to check boresighting in firing position.
- b. Reading powder thermometer incorrectly.
- c. Setting aside one specific case or propellant for powder temperature control for too long a period of time.
- d. Firing rounds from oily tubes.
- e. Failing to set near aiming post one-half the distance to the far aiming post.

CHAPTER 6

FIRING WITHOUT A FIRING CHART

125. Introduction

a. A field artillery battery must be able to deliver timely fire even though a fire direction center is not available to produce firing data. There are numerous solutions for converting the observer's fire requests to fire commands without a complete set of fire direction equipment and a firing chart. This chapter will present a solution that is simple and rapid.

b. Actions that must be taken to fire without a firing chart fall into three phases:

- (1) Determination of data with which to fire the initial round(s).
- (2) Conversion of the subsequent fire requests announced by the observer with respect to the observer-target (OT) line to corrections (in meters) with respect to the gun-target (GT) line.
- (3) Determination of firing data.

126. Occupation of Position

The firing battery occupies position and is laid by using the procedures described in paragraphs 46 through 53. The azimuth on which the executive officer should lay the battery is determined from a knowledge of the situation and reference to a map (if available).

127. Determination of Firing Data for Initial Round(s)

a. The observer sends the initial fire request, following procedures described in chapter 9. The target may be located by any of the methods described in chapter 8.

b. On receipt of the initial fire request, the executive officer must determine the direction and range to the target.

- (1) The executive officer may estimate the direction (azimuth) and range based upon his knowledge of the situation.
- (2) The executive officer may measure direction (azimuth) and range from a map, if available.

c. Deflection may be determined by comparing the azimuth to the target and the azimuth

on which the battery was initially laid and applying the difference to the referred deflection at which the aiming posts were placed.

d. Site can be ignored unless the map (if available) indicates a large difference in altitude between the battery position and the target.

e. Elevation can be determined either from a tabular firing table or a graphical firing table (GFT).

f. Initial fire commands are given in the prescribed manner (pars. 73-94).

128. Determination of Angle

a. The angle T is computed by comparing the observer-target azimuth from the observer's initial fire request and the azimuth from the battery position to the target determined in paragraph 127b. Comparing the two azimuths will also give the relative location (right or left) of the observer with respect to the battery.

b. The M10 plotting board is prepared for use during the adjustment by placing a mark on the rotating disk opposite the number representing the angle T. If the observer is to the right of the battery, the black numbers to the right of the 0-0-32 are used; if the observer is on the left, the red numbers to the left of the 0-0-32 are used. By rotating the disk until the value of the angle T is opposite the red zero on the vernier of the plotting board, a graphical representation of the OT-GT line relationship is obtained. The centerline of the rotating disk represents the OT line. The centerline of the plotting board represents the GT line (fig. 35).

c. The angle T determined initially is retained throughout the mission unless the weapons shift more than 200 mils from the deflection fired on the initial round.

129. Conversion of Observer's Subsequent Fire Requests to Corrections With Respect to the Gun-Target Line

a. During the adjustment, the observer follows normal observer procedures.

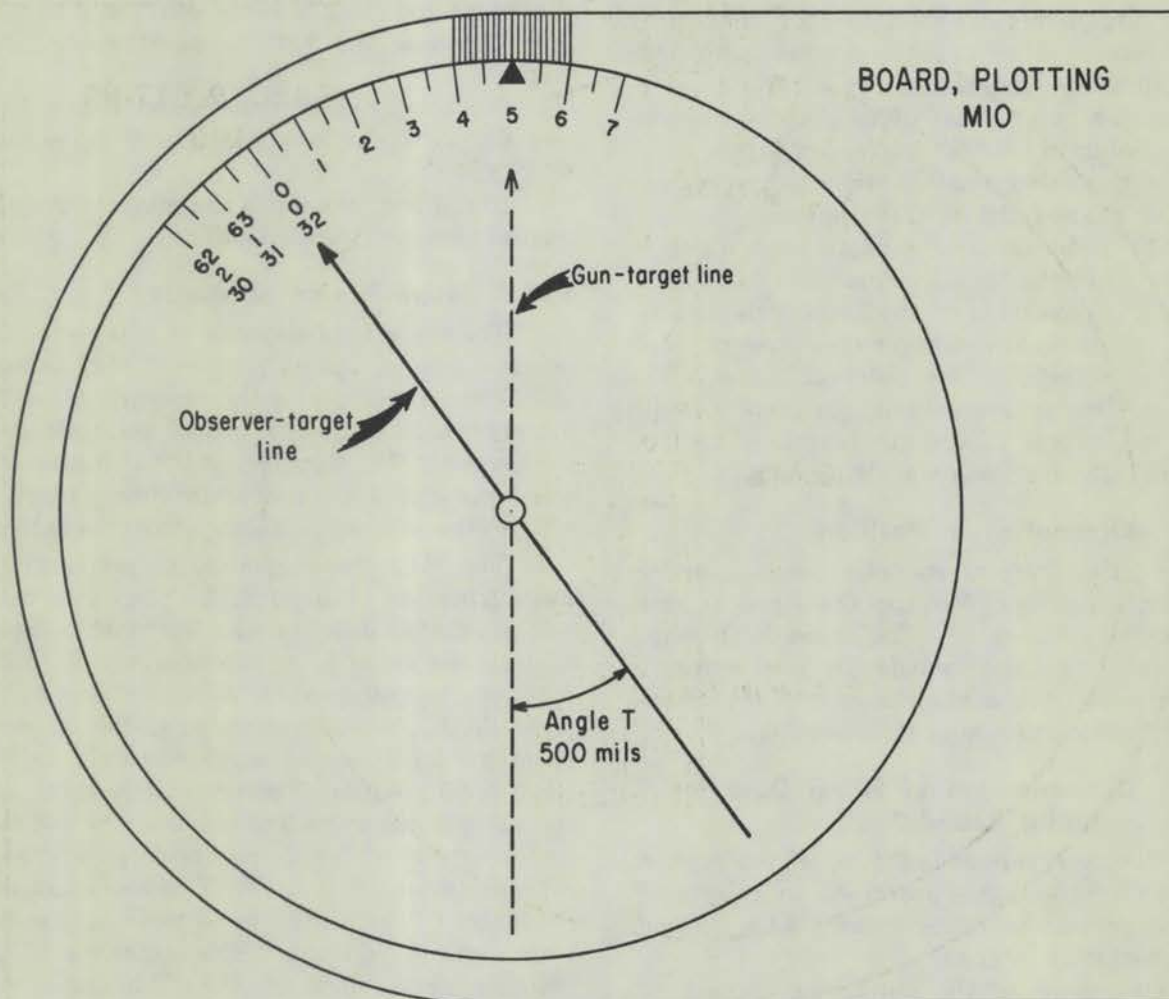


Figure 35. Angle T position.

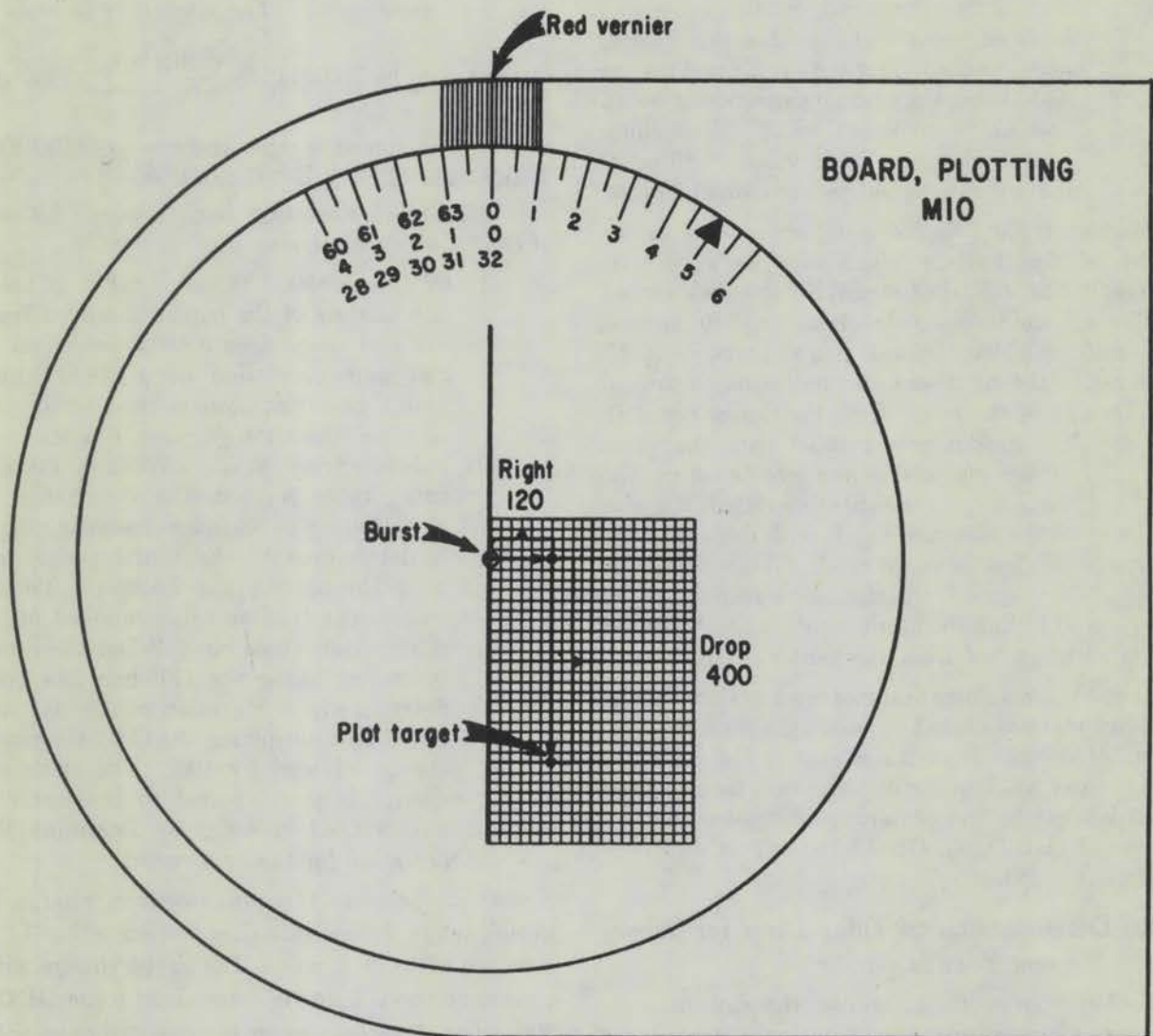


Figure 36. Original position.

b. The observer's shifts are converted to corrections with respect to the GT line, using the M10 plotting board.

- (1) The center of the plotting board always represents the location of the last burst.
- (2) The rotating disk is zeroed (i.e., the 0-0-32 or arrowhead on the centerline is placed opposite the red 0 on the vernier) and the observer's shift is plotted on the disk, using the grid on the plotting board and any convenient scale. Most shifts can be plotted when a value of 10 or 20 meters is assigned to each small square.

Example: Angle T is 500 mils; observer is to the right of the battery. The observer's shift is RIGHT 120, DROP 400. With the disk zeroed and each small square representing 20 meters, the shift is plotted, using pencil mark, 6 small squares to the right and 20 small squares toward the bottom of the board from the center (fig. 36).

- (3) The disk is now rotated until the value of the angle T is opposite the 0 on the vernier. As the disk is rotated, the plot of the observer's shift with respect to the OT line is unchanged. When the angle T is set off, the shift with respect to the GT line (centerline of board) can be measured from the center of the board.

Example: Continuing example from (2) above, the 500-mil mark is placed opposite the 0 on the vernier. The shift from the center of the board to the plotted point on the disk can now be measured with respect to the centerline of the board (GT line) as RIGHT 290, DROP 300. This shift is in meters (fig. 37).

130. Determination of Firing Data for Subsequent Rounds

a. *Deflection.* To determine the deflection, it is necessary to convert the deviation correction (in meters) with respect to the GT line to mils and apply the **correction in mils to the previously fired deflection**. To convert deviation in meters to deviation in mils, it is necessary to multiply the 100/R value for the range to the target by the meter deviation divided by 100. The 100/R value can be computed (100 divided by the range in

thousands of meters) or read from the GFT under the hairline, when the hairline is set over the range. Continuing the example in paragraph 129, the 100/R is determined to be 20 mils. The observer's subsequent request was converted to the GT line, and a deviation correction, in meters, of RIGHT 290, was determined. The deviation in mils is

computed to be RIGHT 58 $\frac{(290 \times 20)}{100}$. The de-

flection announced to the weapons is DEFLECTION 2442 (2,500 + R 58) or (2,500 - 58).

b. *Elevation.* Elevation is determined by one of the following methods:

- (1) *GFT available.* When a GFT is used, the hairline of the cursor is moved from the last range fired an amount equal to the range correction along the GT line, and a new elevation is read under the hairline (elevation gageline, if any).
- (2) *Tabular firing tables.* When a tabular firing table is used, the C (change in elevation for a 100-meter change in range) is determined at the initial range and used throughout the mission. The C used is the tabular value rounded off to the nearest whole mil. When the range correction along the GT line has been determined, an elevation change is computed by multiplying the C by the range change divided by 100. The elevation change is then applied to the last elevation fired in order to determine the elevation for the next round.

Example: Weapon, 155-mm howitzer, charge 5, initial range 5,200, initial elevation 252. C is determined to be 6 mils. The range change with respect to the GT line is determined to be DROP 300. The elevation change is computed to be -18 mils $(300/100 \times 6)$. The elevation for the next round is 234 (252 - 18).

131. Small Angle T

When the angle T is less than 100 mils, the OT line and the GT line may be considered to be the same. The observer's shifts need not be

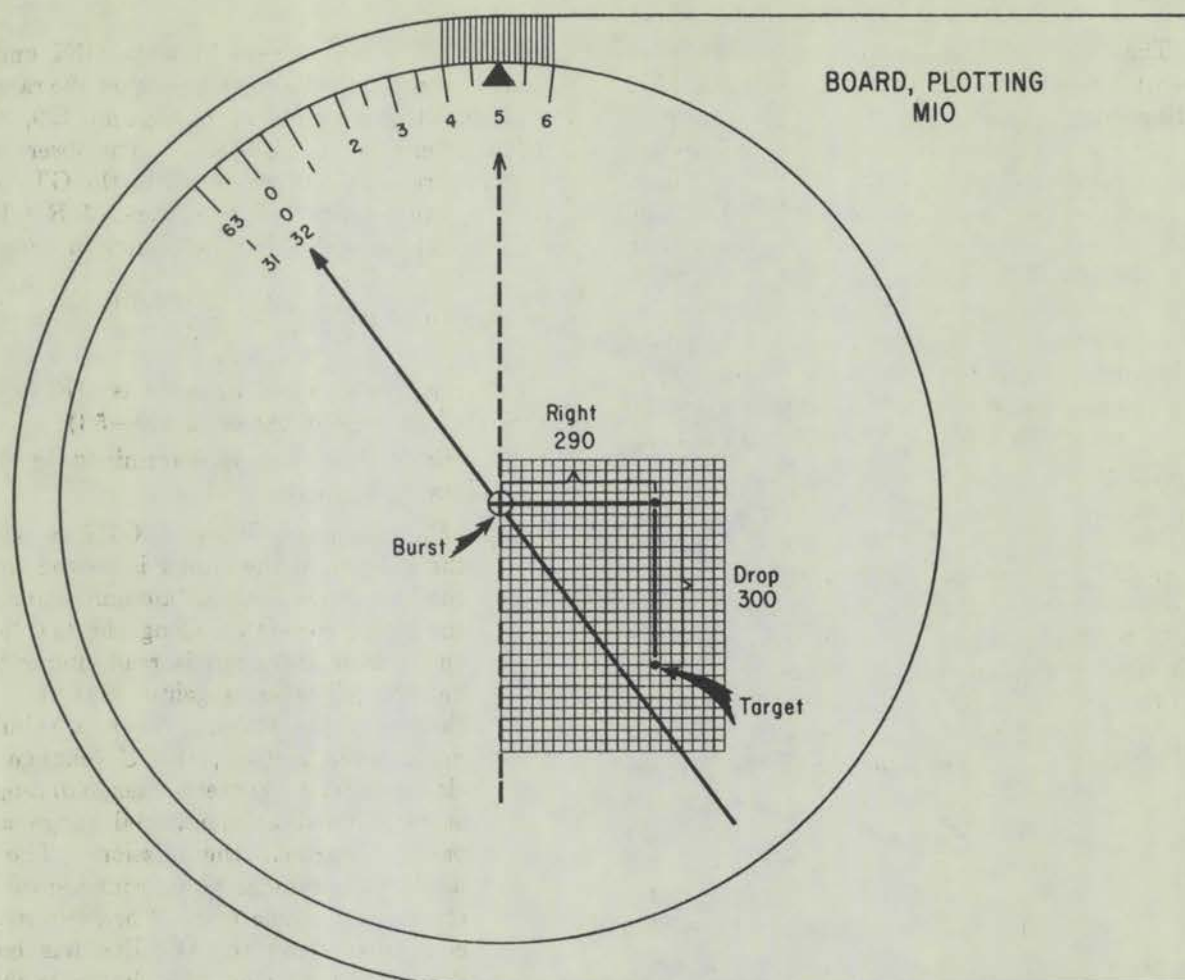


Figure 37. Determining corrections with respect to gun-target line.

converted to the GT line but may be converted directly to firing data by using the procedure described in paragraph 130.

132. Procedure When M10 Plotting Board Is Not Available

When the M10 plotting board is not available,

the executive officer may direct the observer to adjust with respect to the GT line. The observer's shifts are then converted directly to firing data by using the procedure described in paragraph 130.

PART THREE

OBSERVER PROCEDURES

CHAPTER 7

FIELD ARTILLERY OBSERVATION

Section I. INTRODUCTION

133. General

a. Field artillery usually is employed in a manner requiring some type of observation. This observation may be visual, it may be electronic, or it may be indirect observation through study of aerial photographs.

b. Electronic devices generally fall into two classes—radar ranging equipment and sound ranging equipment. Employment of these devices is described in FM 6-122 and FM 6-160.

c. Observer procedures discussed in this manual pertain solely to visual observation and include both air and ground observer techniques. Whenever appropriate, these techniques are explained in the light of their relationship to other phases of gunnery, primarily the fire direction phase.

d. Target grid procedures, on which fire direction (part four) and observation are based, relieve the observer of many functions normally required of him by other gunnery systems. However, the importance of the observer as a vital member in the gunnery team must be emphasized. The observer is the only member of the gunnery team who can actually see the enemy forces, the friendly forces, and the fires placed on the enemy by all combat arms. His ability to observe and his knowledge of the battle situation must be exploited to assist in keeping his unit adequately informed at all times. Moreover, the observer must know and understand the problems and procedures of the fire direction center. He can then combine this

knowledge with his own judgment to effectively assist the gunnery team in fulfilling its purpose.

134. Purpose

Observation is employed by artillery for four purposes: target acquisition, adjustment of fires when necessary, surveillance of fire for effect, and battlefield surveillance.

a. Target acquisition is concerned with detecting suitable targets and determining their ground locations. This information is reported to the FDC where it is used in the production of firing data.

b. Adjustment of fires is necessary to obtain effective fire on the target when the accuracy of target location data is questionable.

c. Surveillance of fire for effect is a follow-through of target acquisition. Since the observer can see the target, he can direct fire and report its effect to the fire direction center. This report should include an accurate account of damage and any appropriate shifts necessary to make the fire more effective.

d. Battlefield intelligence is a very important by-product of artillery observation. Observers must report everything which they observe. Information not necessary for the conduct of fire must be reported promptly, but such action must not delay fire missions.

135. Duties of the Observer

For a discussion of field artillery observer duties and tactics, see FM 6-20-1 and FM 6-140.

Section II. PREPARATORY OPERATIONS

136. General

The observer's preparatory operations contribute to his speed and accuracy in locating targets and reporting information to the fire direction center.

a. Before occupying an observation post (OP) or joining the infantry or tank company that he is to support, the observer should—

- (1) Check equipment.
- (2) Report to the proper artillery and infantry (tank) personnel for briefings.
- (3) Brief his party.
- (4) Make a map reconnaissance.
- (5) Check communications.

b. Upon occupying an OP or joining the infantry (tank) company that he is to support, the observer should—

- (1) Check communications.
- (2) Orient his map and plot those points, the location of which can be determined.
- (3) Report his location to fire direction center.
- (4) Prepare an observed fire (OF) fan.
- (5) Prepare a terrain sketch to supplement the map.
- (6) Prepare fire requests for points at which targets may appear.

c. A fire mission is not delayed merely to complete preparatory operations.

137. Orienting for Direction

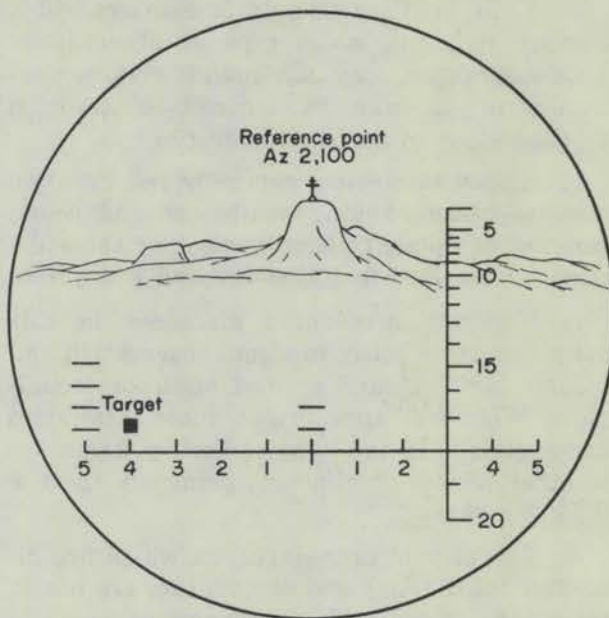
a. Target grid procedures require that the grid azimuth from the observer to the target be determined and reported to the fire direction center. The observer should orient himself for direction by determining and recording the grid azimuth to a number of sharply defined terrain features that he has chosen as reference points.

b. Grid azimuths are normally measured with a declinated magnetic instrument. Azimuths may also be measured from a map when the observer's position is known and plotted.

c. After a number of reference point azimuths have been recorded, the observer can determine the azimuth to any other point in the target area by measuring, with the horizontal mil scale in his binoculars, the angle

from a reference point to the desired point. In figure 38, the target is 40 mils left of the reference point. Azimuth to the target is 2,060 mils (2,100 — 40).

d. The tank-mounted observer is faced with a special problem in determining direction. Magnetic instruments will not function properly in a tank. If the tank is stationary and the observer knows his location, azimuths can be measured from a map. If the tank is moving, the problem becomes more difficult.



Vertical scale on right of lens is not used by the FO in determining data for his fire request. It is used primarily by the Infantry for siting automatic weapons.

Figure 38. Use of reference point azimuth and binocular scales to determine azimuth to target.

138. Location of Known Points

To facilitate the location of targets, the observer and FDC select points in the target area which can be identified by the observer and which are plotted on the firing chart. The location of the *known points* may be determined from maps, by survey, or by firing.

139. Location of the Firing Battery

Although target grid procedures do not require the observer to know the location of the

battery which is firing his mission, a knowledge of the location of the battery will give the observer a greater appreciation of the effects he observes and will facilitate adjustment.

140. Auxiliary Map Data

a. When the observer has completed his initial orientation, he begins a systematic augmentation of map data. This augmentation consists principally of recording information on his map and preparing a terrain sketch. As time permits, a visibility diagram is also prepared.

b. The map is augmented with lines of direction radiating from the observer's position at convenient angular intervals. These lines are intersected with arcs of distance by using the observer's position as the center (fig. 39). The observer then marks points of importance which were not included on the map when printed. He also marks any points which he might frequently need, such as reference points, registration points, concentrations, and likely points of enemy activity.

c. An observed fire (OF) fan may be used instead of marking a map as in *b* above. The observed fire fan (fig. 40) is a fan-shaped protractor constructed of transparent material, covering a 1,600-mil sector. This fan is divided

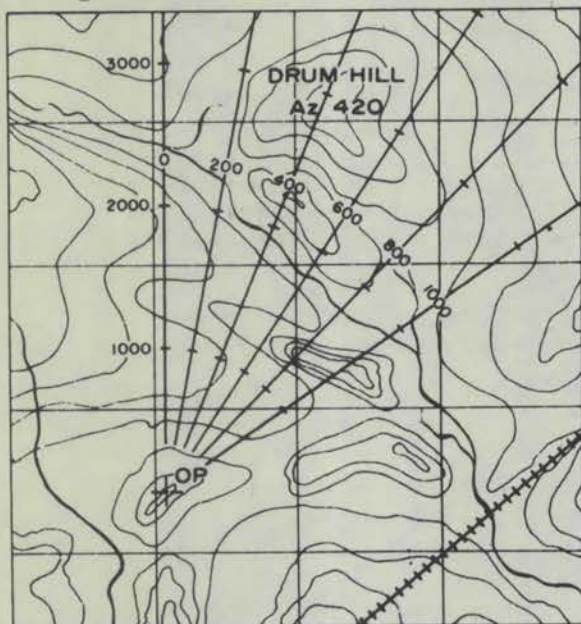


Figure 39. Map augmented to show lines of direction and distance from the observer position.

by radial lines 50 mils apart. Arcs representing distances (scale of 1:50,000) from the OP are printed on the fan in increments of 500 meters from 1,000 to 6,000 meters. To use the OF fan, the observer orients it on his map with the vertex on his OP location in such a manner that the fan is approximately centered on the zone of observation and so that one of the radial lines is parallel to a grid line or other line of known direction. The fan is then taped or tacked to the map. The line of known direction is labeled with its correct azimuth. The other radial lines are then labeled with their azimuths. If desired, only the 100-mil azimuth lines are labeled.

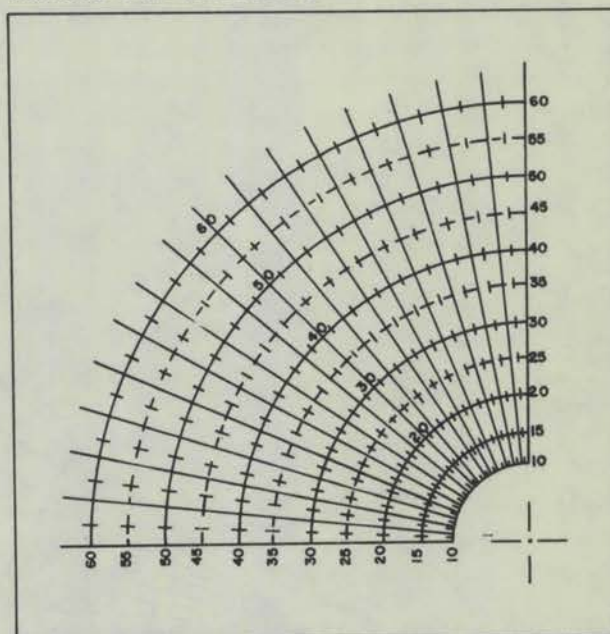


Figure 40. The observed fire fan.

d. Another device which the observer uses to assist in the location of targets is the terrain sketch (fig. 41). This is a panoramic representation of the terrain, sketched by the observer. The sketch shows reference points, registration points, concentrations, and points of probable activity. The terrain sketch is also a rapid means of orienting relief personnel.

e. When available, photographs of the area of observation should be marked, showing pertinent points and lines of direction, and used in conjunction with the terrain sketch. Copies of the photograph and the terrain sketch may be required for reference at the fire direction center.

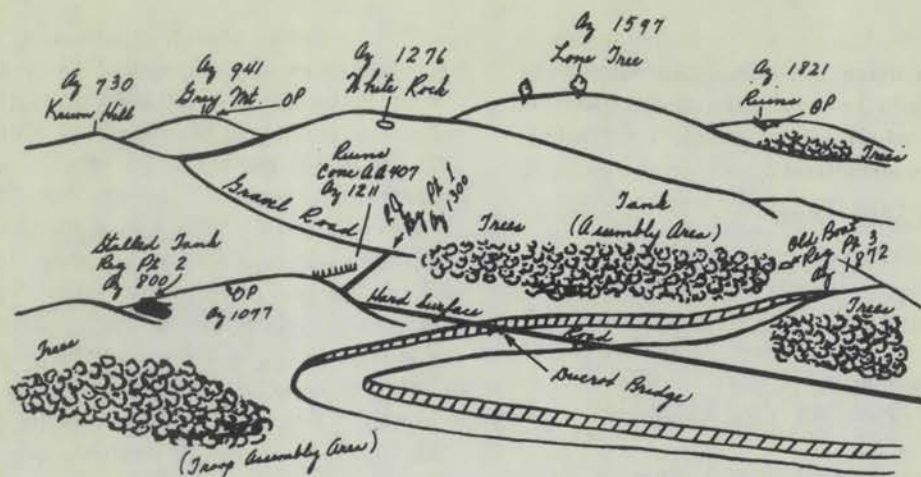


Figure 41. Terrain sketch.

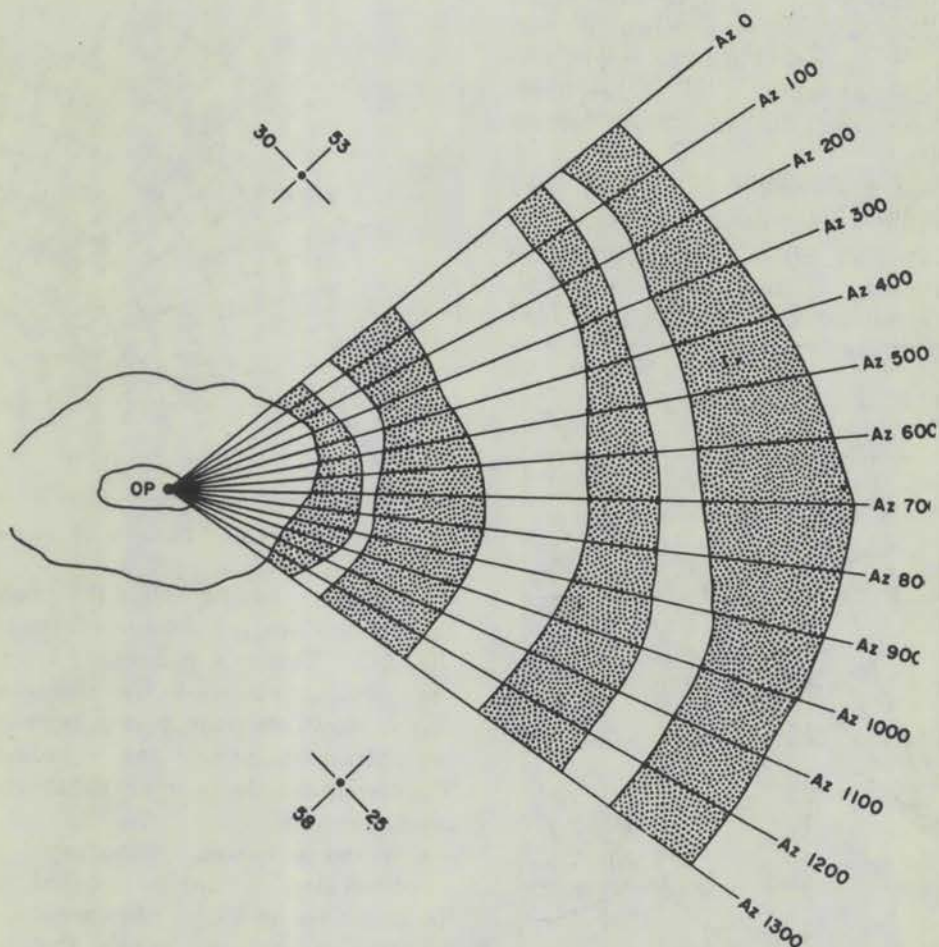


Figure 42. Construction of visibility diagram using direction rays.

f. The visibility diagram (fig. 42) is a sketch of the area of observation, drawn to map scale, showing those portions which cannot be observed from a given observation post. This diagram may be prepared by observer personnel or by FDC personnel if the position of the OP is plotted on FDC maps.

- (1) When the observer prepares the visibility diagram, a copy on overlay paper is sent to the fire direction center. The diagram is prepared by constructing profiles of the terrain along radial lines emanating from the OP (FM 21-26). Except in very symmetrical terrain, each adjacent pair of rays should form an angle no greater than 100 mils. When the profile along each ray is completed, straight lines are drawn from the observer's position to each point of high ground in the field of observation. These rays represent lines of vision; all ground areas between a peak point of tangency and the intersection of ray with the ground are blind spots (fig. 43). These blind spots are projected to the

base of the diagram and transferred to the appropriate line of direction on the observer's map or on a piece of overlay paper. Related points are connected and blind areas are shaded (fig. 42).

- (2) Use of visibility diagrams will reduce the chance of observer error in reporting target locations. If the target is plotted in an area which is not visible, the location data are obviously in error. The diagram aids the S2 in evaluating target area coverage and in determining the best locations for additional observation posts.

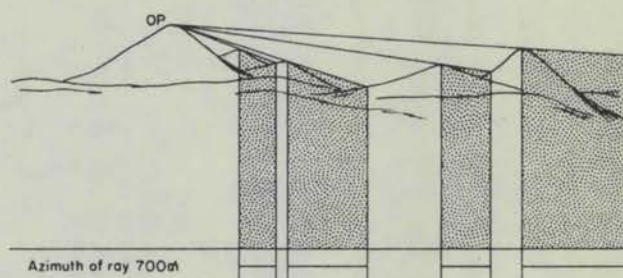


Figure 43. Use of profile to show blind spots (shaded areas).

CHAPTER 8

LOCATION OF TARGETS

141. General

In locating targets and determining initial data, the most accurate means available are employed in order to save ammunition, to save time in adjustment, and to increase effectiveness of fire. To obtain this initial accuracy, data are used from all previous firing in the area as well as maps, photographs, diagrams, or panoramic sketches of the area. The preparatory operations discussed in chapter 7 are desirable and necessary; however, failure to complete them on occupation of an OP will not preclude the observer calling for fire as soon as targets are observed. Firing often begins before the preparatory phase is completed. The firing may be precision fire, which places fire on a specific point, or area fire, which covers a given area with fire. With either type of fire, the observer processes the mission through the FDC by using a standard sequence and procedure. The sequence is as follows:

- a. Target location.
- b. Preparation and submission of a fire request.
- c. Adjustment of fire, if necessary.
- d. Surveillance of fire for effect.

142. Target Location

a. *Methods.* An observer employs three methods of stating the location of targets so that FDC personnel may plot them on their charts. These methods are—

- (1) Grid coordinates (par. 145).
- (2) Reference to point of known location (par. 146).
- (3) Polar coordinates (par. 147).

b. *Accuracies and Announcement of Data.* All data for target locations in initial and subsequent fire requests are determined to an accuracy consistent with the equipment used for determination. The observer will, normally, round off and announce his data as follows:

- (1) Azimuth to nearest 10 mils.
- (2) Deviation to nearest 10 meters.

- (3) Vertical change to nearest 5 meters.
- (4) Range to nearest 100 meters.
- (5) Coordinates to nearest 10 meters.

143. Determination of Distance

The observer must be able to determine quickly and accurately the distance between objects, targets, or bursts in order to determine basic data and to adjust artillery fire effectively. Distances can be determined by estimation or computation.

a. *Estimation of Distance.* Estimation of distance is facilitated by establishing a yardstick on the ground in the target area. This yardstick can be established by firing 2 rounds from the same piece 400 meters apart in range. The observer can also establish a known distance in the target area by determining from his map or photograph the distance between two points, which he can identify positively both on the map and on the ground. The approximate distance from the observer to a sound source (bursting shell, weapon firing, etc.) can be estimated by timing sound. (Speed of sound in still air at 59° F. is approximately 340 meters per second. Wind and variation in temperature alter this speed somewhat.) For practical use by the observer, the speed of sound may be taken as 350 meters per second under all conditions. The sound can be timed by a watch or by counting from the time a burst or flash appears until the sound is heard by the observer. For example, the observer counts "one 1,000, two 1,000," etc., to determine the approximate time in seconds. The time in seconds is multiplied by 350 to obtain the approximate distance in meters.

Example: The observer desires to determine the approximate distance from his position to a burst. He begins counting when the burst appears and stops counting when he hears the sound. He counted 4 seconds; therefore, the burst was approximately 1,400 meters (350×4) from his position.

b. *Computation of Distance.* Distance may be computed by using the angle measured from one point to another and the known lateral distance between the two points. By applying the mil relation formula, the distance from the observer may be computed. The mil relation formula is based on the assumption that a width of 1 meter will subtend an angle of 1 mil at a distance of 1,000 meters. The formula is expressed as $\text{mil} = \frac{W}{R}$, where mil is the angular

measurement in mils between the two points, R is the distance in thousands of meters to the known point, and W is the width in meters between the points from which angle mil was measured (fig. 44).

Example: An observer measures an angle of 5 mils between the ends of a flat car which is 15 meters long. To determine the distance from

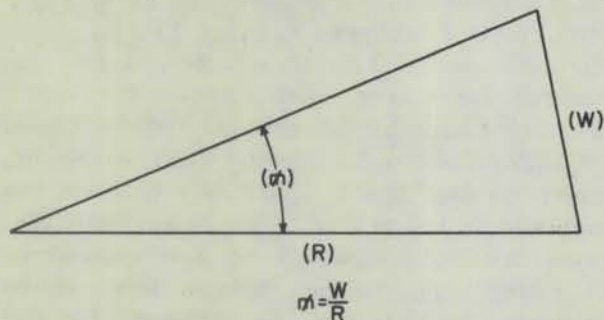


Figure 44. The mil relation.

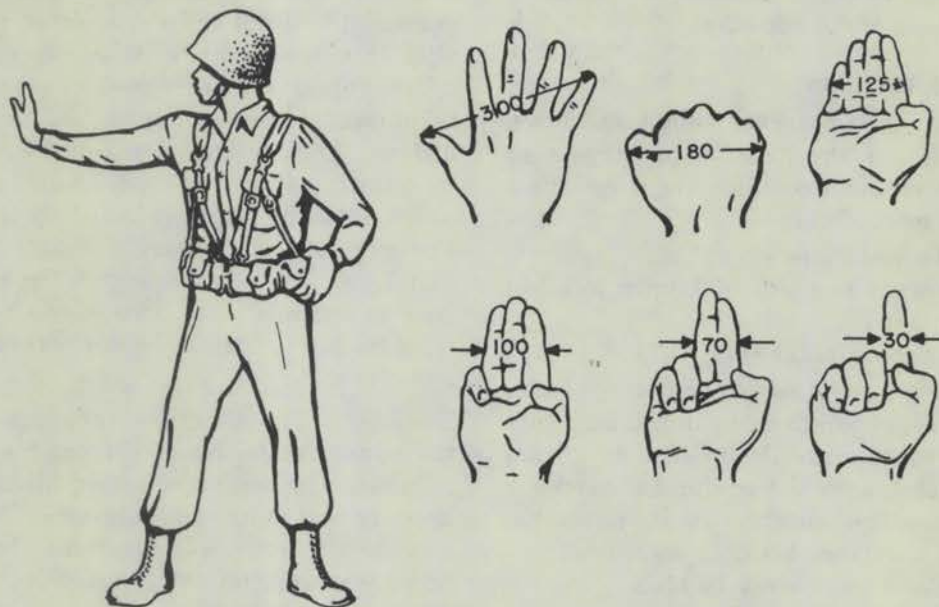


Figure 45. Examples of measuring angles with the hand.

the observer to the flat car, substitute into the formula $R = \frac{W}{\text{mil}}$ ($R = \frac{15}{5}$). The distance is 3,000 meters.

144. Measurement of Angles

An observer usually uses some angle measuring device such as fieldglasses, aiming circle, or battery commander's telescope, (BC scope), to measure angles. When instruments are not available, angles can be measured by using the hand and finger held at a fixed distance from the eye. The specific angle subtended by the hand in various attitudes must be determined by the individual before he goes into the field and must be recorded and memorized for rapid use (fig. 45).

145. Target Location by Grid Coordinates

a. Auxiliary map data greatly simplifies the determination of accurate coordinates of a target. When the observer sees a target that is located where it cannot be plotted by rapid inspection, his first step is to determine the target azimuth. He determines the azimuth by using any of the methods described in paragraph 137.

b. Having determined the azimuth and his location, the observer refers to the corresponding line of direction on the map (or observed

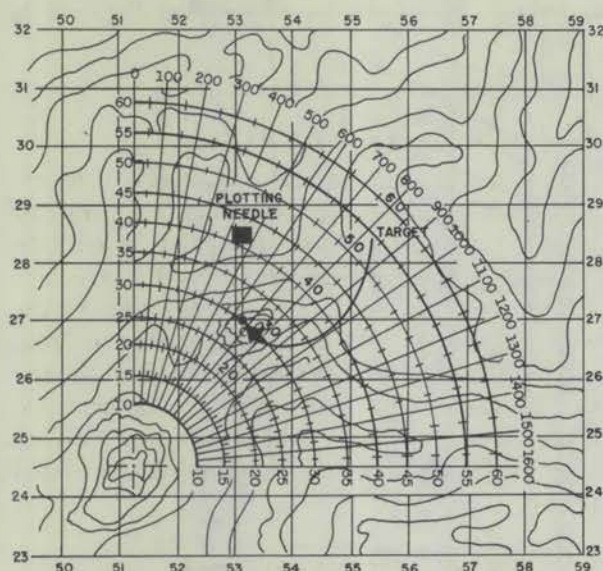


Figure 46. Use of observed-fire fan to assist in reading coordinates.

fire fan). He selects the point on this line which best describes the target location. He may locate this point by comparing map features with ground features or by estimating the distance from his position to the target. In figure 46, the observer has measured an azimuth of 680 mils to a target which is located on a small hill an estimated 3,000 meters from the observer's location. He has pinpointed the target on the map by plotting a distance equivalent to approximately 3,000 meters along a ray corresponding to azimuth 680 mils on the observed

fire fan. A study of the contour lines aids the observer in estimating the range more accurately.

c. After locating the target on the map, the observer marks the location and determines the coordinates with a coordinate scale or by estimation. When properly used, the coordinate scale enables the observer to measure both easting (E) and northing (N) coordinates with one placement of the scale. To measure the coordinates of a target, the observer first determines the coordinates of the lower left-hand corner of the grid square containing the target. Starting at this grid intersection, he slides the coordinate scale to the right, keeping the horizontal scale in coincidence with the E-W grid line, until the target is reached by the vertical scale. He then reads the distance east and the distance north from the scale (fig. 47) and adds these readings to the coordinates of the grid square to obtain the coordinates of the target; i.e., 53152475.

d. Coordinates may also be determined by relating the target location to one of several ground features marked on the map. This system should be used with extreme care, especially in deceptive terrain, unless the location is such as to preclude error (road junction, building, bridge, etc.). A rapid check of the accuracy of coordinates can be made by use of contour lines on the map. If the plotted altitude of a target shows marked disagreement with the actual ground conformation, the target should be replotted.

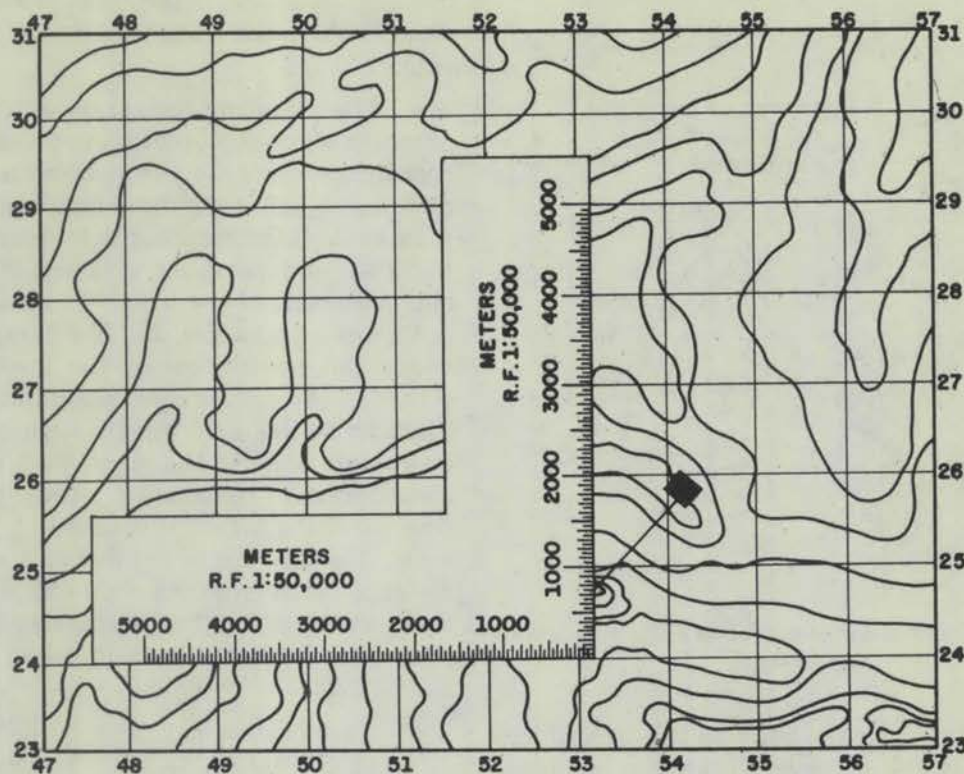


Figure 47. Use of coordinate scale.

146. Target Location by Shift From a Known Point

In order to locate a target by a shift from a known point, FDC personnel must have the location of the known point plotted on their charts. Either the observer or S3 may select points for use as known points, but both observer and FDC personnel must know their locations, and designations. Registration points prominent terrain features, and previously fired concentrations are commonly used as known points. The location of a target by shift from a known point requires the observer to determine the observer-target azimuth, a horizontal shift, and a vertical shift.

a. Observer-Target Azimuth. The observer-target (OT) azimuth is normally determined by measuring the angular deviation from one

reference point to the target and applying the measured deviation to the azimuth from the observer to the reference point. The measured deviation is added if the target is to the right of the reference point and subtracted if the target is to the left of the reference point. Observer-target azimuth may also be measured with a properly declinated magnetic instrument.

b. Horizontal Shift. The horizontal shift from a known point to the target consists of a lateral shift in meters and a shift in range along the OT line. The lateral shift is made from the known point along a perpendicular dropped from the known point to the OT line at the point (T') at which the perpendicular intersects the OT line. The shifts are plotted in the FDC on a target grid oriented on the OT azimuth. The method used by the observer to compute the horizontal shift depends on the

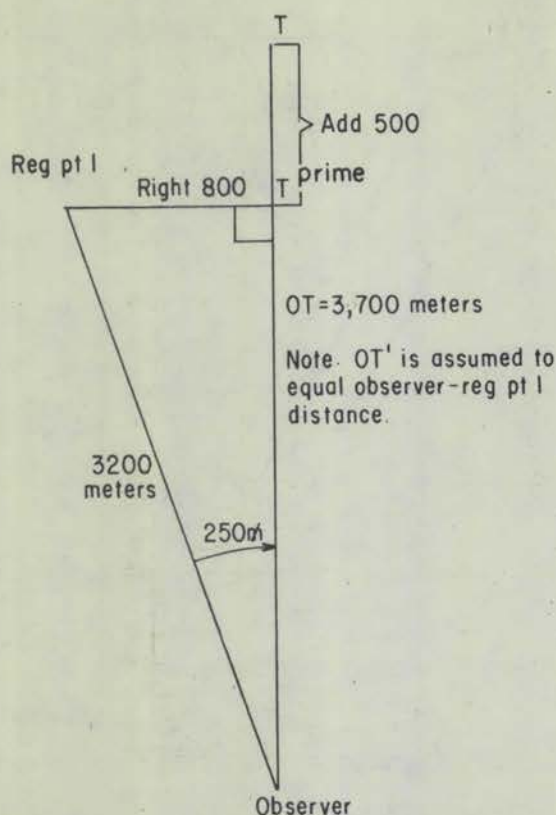


Figure 48. Computation of lateral and distance shift.

size of the angular deviation measured from the known point to the target.

- (1) *Deviation of less than 600 mils.* When the angular deviation from a known point to the target is less than 600 mils, the mil relation formula (par 143b) is used to compute the lateral shift. The shift in range is determined by comparing the distance from the observer to the known point to the distance from the observer to the target.

Example: An observer measures an angular deviation from registration point 1 to the target of right 250 mils. He knows the distance to registration point 1 to be 3,200 meters and estimates the distance to the target to be 3,700 meters (fig. 48). The lateral shift is determined by substituting in the formula $W = R\phi$ ($W = (3.2) \times 250$) or 800 meters. The range shift is add 500 ($3,700 - 3,200 = 500$ meters). The shift is announced as RIGHT 800 ADD 500.

- (2) *Deviation of 600 mils or greater.* When the angular deviation from a known point to the target is 600 mils or greater, the accuracy of the mil relation formula breaks down. In such a situation, trigonometric functions must be used to determine horizontal shifts. Trigonometry (trig) is a study of triangles. A trigonometric function is merely the ratio between two sides of a right triangle. One of these trigonometric functions is the sine (sin).

The sine of an angle $A = \frac{\text{side opposite angle } A}{\text{hypotenuse}}$ (fig 49).

The formula for use of sine factor is $F = \frac{W}{D}$, where F is the sine factor

for the angular deviation ϕ (value taken to the nearest 100 mils), D is the distance to the reference point (hypotenuse), and W is the width of the side opposite the angle ϕ . Note that D , or distance, is not reduced to units of thousands of meters when sine factors are used. The sine factors are—

Angle in mils	Sine factor
100	0.1
200	0.2
300	0.3
400	0.4
500	0.5
600	0.6
700	0.6
800	0.7
900	0.8
1,000	0.8
1,100	0.9
1,200	0.9
1,300	1.0
1,400	1.0
1,500	1.0
1,600	1.0

The lateral shift is computed by substituting in the formula $W = F \times D$ where F is the sine factor of the angular deviation from a known point to the target and D is the distance (to the nearest 100 meters) to the known point.

To determine the range shift, it is first

necessary to determine the distance from the observer to the point at which a perpendicular from the known point to the OT line strikes the OT line (T'). To accomplish this, substitute again in the formula $W = F \times D$ where, this time, F is the sine factor of the angle complementary to the angular deviation and D is, again, the distance from the observer to the known point. The range shift is determined by comparing the OT' distance and the observer-target (OT) distance.

Example: An observer measures the angular deviation from registration point 1 to the target as left 700 mils. The distance from the observer to registration point 1 is 2,500 meters and the estimated distance from the observer to the target is 3,100 meters (fig. 50).

Solution: Lateral shift equals $W = 0.6$ (sine factor for 700 mils) $\times$ 2,500 or left 1,500. $OT' = W = 0.8$ (sine factor for 900 mils, the complement of 700 mils) $\times$ 2,500 = 2,000 meters. Range shift is ADD 1100 (meters).

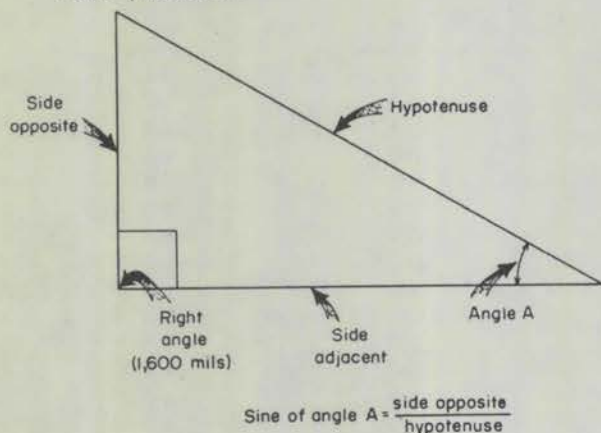


Figure 49. Sine function.

c. **Vertical Shift.** In the shift from a known point method, a vertical shift must be made if there is a difference in the altitudes of the known point and the target. The vertical shift may be estimated or computed. The following procedure is used to compute a vertical shift: The observer measures the vertical angle to the known point. Knowing the distance from his OP to the known point and using the mil rela-

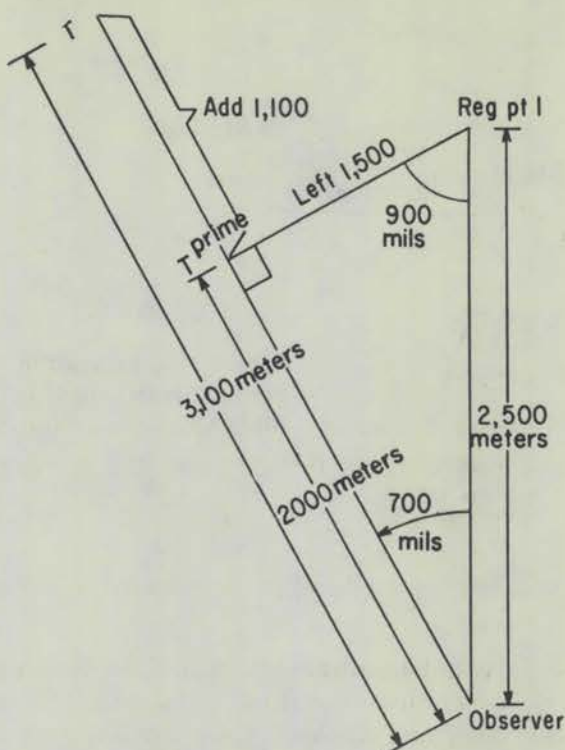


Figure 50. Computation of lateral and distance shift using sine factors.

tion, the observer determines the vertical interval or the amount in meters that the known point is above or below his observation post. He then computes the vertical interval between his OP and the target. By comparing the known point vertical interval to the target vertical interval, he determines the vertical change (up or down) from known point to target.

Example (fig. 51). The observer measures a vertical angle of minus 10 mils between the OP and a target at a distance of 2,500 meters. The distance and the vertical angle from the OP to the known point are 1,500 meters and minus 20 mils, respectively. In the formula $W = R\phi$, let W represent the vertical interval, ϕ represent the measured angle in mils, and R represent the distance to the target (known point) in thousands of meters. Therefore, $W = -10 \times 2.5 = -25$ meters vertical interval between OP and target. By using the same procedure, the vertical interval between the OP and the known point is -30 meters ($W = 20 \times 1.5$; $W = -30$). A comparison of results shows the target to be 5 meters above the known point. Thus, the vertical shift would be announced as UP 5.

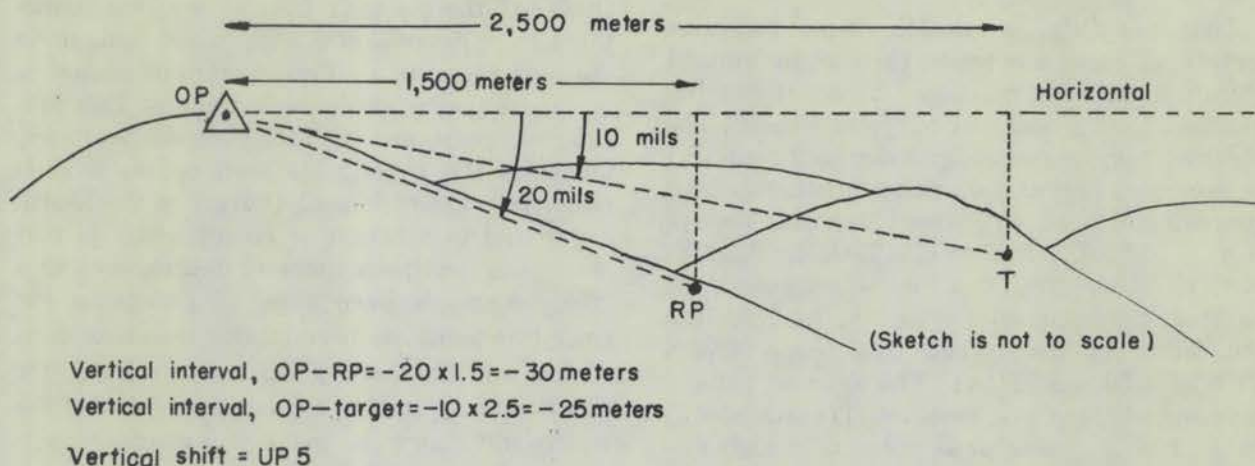


Figure 51. Determination of difference in heights of known point and target.

147. Target Location by Polar Coordinates

Polar coordinates consist of the azimuth, vertical shift, and distance from the observer to the target. The observer's location must be plotted on the charts at the FDC if the polar coordinate method is to be used. The principal advantage of the polar coordinates method is the rapidity with which the observer can determine the target location. If the azimuth is correct, the first round(s) fired should fall on or close to the line which passes through the OP and the target (OT line). Subsequent shifts are then easier to determine. As in the grid coordinate method, the observer measures or computes the azimuth and estimates the distance to the target. In figure 52, the polar coordinates of the target would be reported to the FDC as AZIMUTH 1000, DISTANCE 1400. A vertical shift must be made if there is a difference in altitude between the observer's location and the target. The observer, using a BC scope, aiming circle, or M2 compass for accurate measurement or binoculars for an approximation, measures the vertical angle to the target. This vertical angle is measured from the horizontal plane through the observer's location to the target. Substituting this measured vertical angle and the estimated distance to the target, for η and R, respectively, in the mil relation formula, the observer computes the vertical shift.

Example: The measured vertical angle locates the target at 20 mils above the observation post. Estimated distance to target from the OP is 2,000 meters. Using the mil relation, $20 = \frac{W}{2.0}$

$W = 40$ meters. A vertical shift would then be included as follows: AZIMUTH 1000, UP 40, DISTANCE 1400.

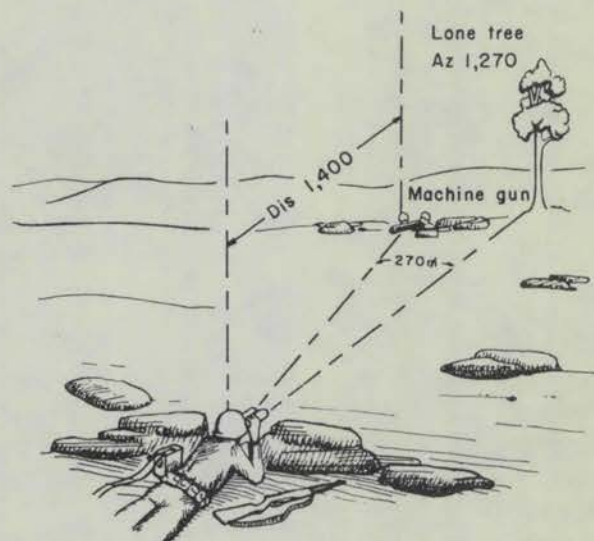


Figure 52. Polar plot.

148. Marking Rounds

Poor visibility, unreliable maps, deceptive terrain, or rapid movement through unfamiliar terrain sometimes make it difficult, if not impossible, for the observer to orient himself. The observer may request that a marking round(s) be fired on a registration point, previously fired concentration, or prominent terrain feature (e.g., MARK REGISTRATION POINT; MARK HILL 437; etc.). As a last resort the observer may request a round(s) be fired into the center of the target area (e.g., MARK CENTER OF SECTOR). The observer usually requests a type of projectile that is easily identifiable, such as white phosphorus or a high air-burst. The FDC prepares data which will place

the round(s) where the observer has asked for them. If the observer fails to see this round, the FDC prepares new data which will move the next round to a different point of impact or will raise the burst higher in the air. This procedure is continued until the observer positively identifies the round. He then orders a shift from the point of impact (burst) of the identified round to a target or object which is permanent or semipermanent in nature, such as a tree, crossroads, barn, ruins of a building, etc. Once this point has been located by adjustment of fire and has been plotted at the FDC, the observer may use it as a known point from which shifts may be made to subsequent targets.

CHAPTER 9

FIRE REQUESTS

149. Elements and Sequence of Fire Request

a. When an observer desires to fire on a target, he transmits a fire request. The fire request is a concise message prepared by the observer containing the information needed at the FDC for the preparation of fire commands. The fire request contains nine elements arranged in a prescribed sequence. Any of these elements may be omitted when not pertinent to a fire mission.

b. The following is a list of the elements and the sequence in which they are transmitted:

- (1) Identification of observer.
- (2) Warning.
- (3) Location of target.
- (4) Nature of target.
- (5) Classification of fire.
- (6) Type of adjustment.
- (7) Type of projectile.
- (8) Fuze action.
- (9) Control.

150. Identification of Observer

The element identifying the observer consists of appropriate call signs or codes necessary to establish contact between the observer and the unit from which he is requesting fire. For example, the observer transmits STALLION 9 (call sign of the FDC) THIS IS STALLION 31 (observer's call sign).

151. Warning

The warning element is the notice sent by the observer to achieve communication priority and to alert the fire direction center. It is announced as FIRE MISSION.

152. Location of Target

a. When the target is located by grid coordinates, the elements of the target location are transmitted in the following sequence:

- (1) Coordinates; e.g., COORDINATES 46913961.
- (2) Azimuth (OT); e.g., AZIMUTH 4960.

b. When the target is located by a shift from a known point, the elements of the target location are transmitted in the following sequence:

- (1) Known point; e.g., FROM REGISTRATION POINT 1.
- (2) Azimuth (OT); e.g., AZIMUTH 4960.
- (3) Lateral shift (if any); e.g., LEFT (RIGHT) 460.
- (4) Vertical shift (if any); e.g., UP (DOWN) 30.
- (5) Range shift; e.g., ADD (DROP) 500.

c. When the target is located by polar coordinates, the elements of the target location are transmitted in the following sequence:

- (1) Azimuth (OT); e.g., AZIMUTH 4960.
- (2) Vertical shift; e.g., UP 30.
- (3) Distance (OT); e.g., DISTANCE 4100.

153. Nature of Target

The element indicating the nature of the target includes a description of the installation, personnel, equipment, or activity which is observed. This description should be brief but sufficiently informative to enable the S3 to determine the relative importance of the target and the best manner of attack. The observer should state the approximate number of personnel or units of materiel comprising the target; e.g., 50 INFANTRY AND 3 TANKS IN THE OPEN. He should give a clear description of the target to include the shape when it is significant; e.g., 60 INFANTRY DIGGING IN ALONG RIDGE LINE. He should indicate the approximate size of a target that covers a large area; e.g., TRUCK PARK IN WOODS, 300 BY 300. The size of the target is omitted for a precision registration.

154. Classification of Fire

Fires are classified as close when they are within 600 meters of friendly troops. Use of the classification-of-fire element is optional in the adjustment of ground artillery fire but mandatory in the adjustment of naval gunfire.

(For naval gunfire procedures, see app. IV.) This element may be required by a unit commander when other provisions, such as no-fire lines, do not guarantee safety of the friendly troops.

155. Type of Adjustment

a. In adjustment, two types of fire may be employed, area or precision. When a precision adjustment is desired, the observer specifies either registration or destruction, depending on the reason for firing. Only one piece is used during a precision adjustment. If no specific type of adjustment is designated, area fire will be used.

b. Two choices of trajectory for the adjustment may be available, low-angle or high-angle. When low-angle fire is desired, the observer omits this element. When high-angle fire is desired, the observer requests HIGH ANGLE. When computations at the FDC show high-angle fire to be necessary, the S3 will notify the observer that high-angle fire will be used.

c. In area fire, the adjustment is conducted by the two center pieces of the battery firing volley fire unless the observer requests otherwise. If firing a volley causes one round to be obscured by the other due to the size of angle T and the location of the GT line with respect to the OT line, the observer may request salvo fire. If the observer desires to adjust with pieces other than the center platoon, he must so indicate in his fire request. Volley fire is normally used in fire for effect.

d. A parallel sheaf is usually fired on an area target in fire for effect. When another type of sheaf is desired, the observer announces the type of sheaf desired; e.g., CONVERGED SHEAF.

e. The observer may indicate the volume of fire desired in fire for effect; e.g., REQUEST BATTALION.

156. Type of Projectile

a. The observer omits the element indicating type of projectile when he desires shell HE.

b. The observer may request one type of projectile initially and subsequently request another type of projectile to complete the fire mission.

c. When the observer requests SHELL SMOKE, the S3 will normally direct the use of shell HE initially in adjustment and shell smoke for completion of adjustment and fire for effect.

d. When the observer wants a combination of projectiles in effect, he must so state in this element of the initial fire request; e.g., SHELL HE AND WP IN EFFECT.

157. Fuze Action

a. The observer omits the element indicating fuze action when he desires fuze quick or when he has no choice in the type of fuze to be used. For example, if he requests either HC smoke shell or illuminating shell, the element indicating fuze action would be omitted since these shells are always fuzed with a time fuze.

b. When the observer wants VT fuze in fire for effect, he requests FUZE VT. The S3 will direct the use of fuze quick in adjustment and VT in effect. If, in an exceptional case, the observer wants fuze VT during adjustment, he must so specify by requesting FUZE VT IN ADJUSTMENT.

c. When the observer wants a combination of fuzes in effect, he must so state in this element of the initial fire request; e.g., FUZE VT AND QUICK IN EFFECT.

158. Control

The control element indicates the control which the observer will exercise over the time of delivery of fire and whether an adjustment is to be made or fire is to be delivered without an adjustment. Method of control is announced by the observer by use of one or more of the terms in *a* through *d* below.

a. *At My Command.* *At my command* indicates that the observer desires to control the time of delivery of fire. The observer announces AT MY COMMAND immediately preceding the announcement of *b* or *c* below; i.e., AT MY COMMAND, WILL ADJUST, or AT MY COMMAND, FIRE FOR EFFECT. When the pieces are ready to fire, the FDC personnel announce BATTERY (BATTALION) IS READY to the observer, after which the observer announces FIRE when he desires the pieces to fire. This method of control remains in effect throughout the mission unless the observer transmits FIRE

WHEN READY, or announces a new method of fire not containing AT MY COMMAND i.e., FIRE FOR EFFECT.

b. *Will Adjust.* *Will adjust* indicates that an adjustment is necessary, that the observer can see and adjust the fire, and that the firing unit may begin firing when ready.

c. *Fire for Effect.* When the location of the target is sufficiently accurate to eliminate the requirement for an adjustment, the observer announces FIRE FOR EFFECT. This type of fire has appreciable surprise value and is preferable. Fire for effect indicates that the observer is ready to observe and that the firing unit may fire for effect when ready. When the observer requests fire for effect, the S3 may decide, from knowledge not available to the observer, e.g., when corrections are not current, that an adjustment is necessary and will so inform the observer. Fire for effect is warranted without adjustment when the target is—

- (1) At a surveyed location.
- (2) At a recently fired concentration.
- (3) On a prominent terrain feature easily identifiable on the ground and an accurate map.
- (4) Large enough that the fire for effect cannot miss the target.

d. *Cannot Observe.* *Cannot observe* indicates that the observer will be unable to adjust the fire; however, he has reason to believe that a target exists at the given location and that it is of sufficient importance to justify firing on it without adjustment.

159. Initial Fire Request

Table V gives examples of initial fire requests with explanations of what the observer can expect from each sample request. The initial fire request is divided into 9 elements some of which contain several sub-elements. When transmitting the fire request, the observer may announce two or more elements in one transmission or divide an element into two or three transmissions commensurate with established procedures and the training and experience of individuals concerned with the conduct of fire.

160. Correction of Errors

a. Errors may be made by the observer transmitting erroneous data or by the FDC per-

sonnel transmitting an incorrect read-back. If an observer recognizes that an error has been made in his transmission or that FDC personnel's read-back was not correct, he announces CORRECTION and transmits the corrected data. If two or more elements or sub-elements of the initial fire request were contained in one erroneous transmission the observer will correct that element or subelement in error provided the remainder of the transmitted data will not be affected by the correction.

Example: The observer has transmitted, FROM REGISTRATION POINT 2, AZIMUTH 4680, OVER and immediately realizes that he should have sent AZIMUTH 5680. He then announces CORRECTION, AZIMUTH 5680, OVER and, after receiving the correct read-back, continues to send the remainder of the fire request.

b. When an error has been made in a sub-element and the correction of that sub-element will affect other transmitted data, the incorrect sub-element and the affected data will be transmitted in proper sequence following the word CORRECTION.

Example: The observer has transmitted LEFT 200 UP 40 ADD 400, OVER. He then realizes he should have sent DROP 400 instead of ADD 400. To correct this element he will send CORRECTION, LEFT 200 UP 40 DROP 400 since the LEFT 200 and UP 40 would have been canceled if not included in the corrected transmission.

c. If the observer has transmitted his entire fire request and then discovers that he has made an error or omitted an element or sub-element, the correct version of that element or sub-element must be transmitted together with other affected data.

Example: The observer sent—
STALLION 9, THIS IS STALLION 31
FIRE MISSION, OVER (FDC reads back)
FROM REGISTRATION POINT 2
AZIMUTH 5680, OVER (FDC reads back)
LEFT 200, UP 40
ADD 400, OVER (FDC reads back)
INFANTRY IN OPEN, FUZE
TIME, WILL ADJUST, OVER (FDC reads back). He then realizes a better fuze to use on this target is VT. To correct this error he must send—CORRECTION, FUZE VT, OVER.

Table V. The Fire Request.

Fire request		Examples				
Element	When omitted	1. Precision registration using surveyed chart.	2. Area mission using polar plot.	3. Destruction mission using shift from known point.	4. Area mission using pre-arranged data.	5. Area mission firing high-angle fire.
a. Identification of observer.	Never.....	THUNDER 9, THIS IS THUNDER 31.	STALLION 9, THIS IS STALLION 31.	COMPOUND 9, THIS IS COMPOUND 31.	KANVAROD 9, THIS IS KANVAROD 31.	RAMROD 9, THIS IS RAMROD 31.
b. Warning.....	Never.....	FIRE MISSION.....	FIRE MISSION.....	FIRE MISSION.....	FIRE MISSION.....	FIRE MISSION.
c. Location of target.	Never.....	REGISTRATION POINT 2, AZIMUTH 4710.	AZIMUTH 5260, DOWN 30, DISTANCE 3200.	FROM REGISTRATION POINT 1, AZIMUTH 2640, RIGHT 500, UP 25, DROP 800.	CONCENTRATION AB 302, AZIMUTH 5040.	COORDINATES 762134, AZIMUTH 4750.
d. Nature of target.	In precision registration.	Omitted.....	20 INFANTRY IN THE OPEN.	BUNKER.....	5 TANKS AND COMPANY OF INFANTRY IN THE OPEN.	MACHINEGUN FIRING.
e. Classification of fire.	When target is deep.	Omitted.....	Omitted.....	Omitted.....	Omitted.....	CLOSE 500.
f. Type of adjustment:						
(1) Type of fire	Area fire.....	REGISTRATION.....	Omitted.....	DESTRUCTION.....	Omitted.....	Omitted.
(2) Trajectory	Low-angle fire.....	Omitted.....	Omitted.....	Omitted.....	Omitted.....	HIGH ANGLE.
(3) Method of fire.	(a) In precision fire.	Omitted.....	SALVO LEFT.....	Omitted.....	Omitted.....	Omitted.
	(b) When center one round is desired.					
	(c) In FFE mission.					
(4) Distribution.	(a) When parallel sheaf is desired.	Omitted.....	Omitted.....	Omitted.....	Omitted.....	CONVERGED SHEAF
	(b) In precision fire.					
(5) Volume FFE.	When applicable.....	Omitted.....	Omitted.....	Omitted.....	REQUEST BATTALION.	Omitted.

g. Type of projectile.	When shell HE is desired.	Omitted.....	Omitted.....	Omitted.....	SHELL HE AND WP.	Omitted.
h. Fuze action.....	(1) When fuze quick is desired. (2) When HC smoke or illuminating shell is requested.	Omitted.....	FUZE TIME.....	Omitted.....	Omitted.....	FUZE VT.
i. Control.....	Never.....	WILL ADJUST.....	WILL ADJUST.....	WILL ADJUST.....	FIRE FOR EFFECT..	WILL ADJUST.

CHAPTER 10

ADJUSTMENT PROCEDURE BY GROUND OBSERVER

Section I. GENERAL

161. When to Adjust

When the observer cannot locate the target with enough accuracy to warrant firing for effect, he will conduct an adjustment. Lack of accuracy in the location may be the result of poor visibility, deceptive terrain, poor maps, or difficulty on the part of the observer in pinpointing the target. If, in his opinion, fire for effect can be delivered on the basis of target location, and surprise is desired, he will request **FIRE FOR EFFECT** in his initial fire request. If in his opinion, fire for effect cannot be delivered on the basis of target location, he will signify the need for adjustment by including **WILL ADJUST** in his initial fire request. If registration has not been accomplished recently, adjustment may be directed by the S3 regardless of the accuracy of the target location.

162. Adjusting Point

The observer must select a point upon which to adjust (adjusting point). In precision fire, the adjusting point is the target. In area fire, the adjusting point should be a well-defined point near the center of the area occupied by the target (fig. 53).

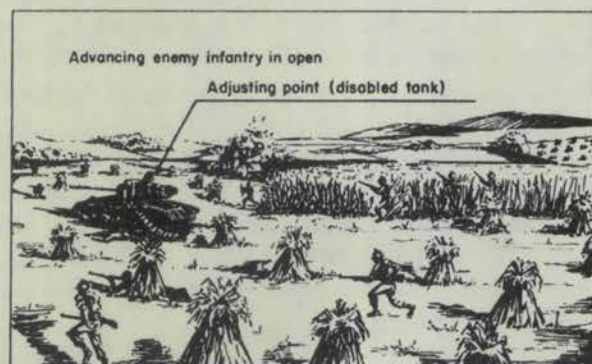


Figure 53. Adjusting point in area fire.

163. Use of Bracket

A basic principle in adjusting artillery fire is to establish a bracket on the target. A bracket is established by rounds falling on opposite sides of the adjusting point. The normal procedure for adjustment is the establishment of a bracket for range along the observer's line of vision (OT line) (fig. 54). Direction and height of burst are normally corrected by the observer without resorting to a bracket.

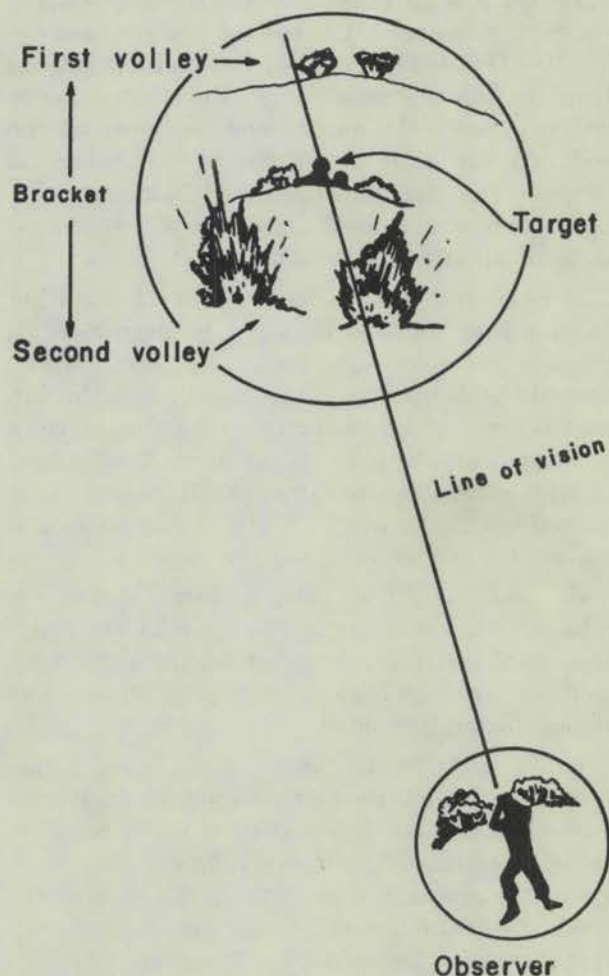


Figure 54. Establishing a bracket for range.

164. Appearance of Bursts

The observer must be able to identify the type of shell and fuze used from the appearance of burst. Descriptions of types of shells and fuzes with which an observer will normally be concerned are given in *a* through *f* below. These types are applicable to all artillery weapons; however, size of the bursts will vary in accordance with the caliber of the weapon.

a. Shell HE, Air Burst, Fuze Time or Fuze VT. A fuze time or fuze VT air burst is characterized by a flash, sharp explosion, and puff of black smoke which become elongated along the trajectory. The effect of fragments on the terrain may be seen below the burst, if the burst is not too high and soil conditions are favorable.

b. Shell HE, Fuze Delay, Ricochet. A ricochet burst is a low air burst characterized by a flash, sharp explosion, and a ball of smoke (usually black). Dirt is kicked up by the shell fragments from the side and base spray. Burst appearance will vary with the nature and condition of the soil and the attitude of the projectile as its bursts. The characteristic flash, black smoke, and sharp explosion of an air burst are indications of an effective ricochet burst.

c. Shell HE, Fuze Quick. A burst resulting from a fuze quick detonation is characterized by black smoke, discolored by dirt, which spreads both upward and laterally. If the impact occurs on a rock or other hard surface, a flash may also appear. Fuze quick fired into a wooded area will sometimes result in air bursts, caused by the projectile striking the trees and detonating before reaching the ground.

d. Shell HE, Fuze Delay, Mine Action. A mine action burst is characterized by the eruption of a vertical column of earth, often with clods of earth. There is very little smoke, and the explosion is muffled.

e. HC and Colored Smoke, Fuze Time. Functioning of an HC or a colored smoke shell with fuze time is characterized by a small burst in the air, produced by the expelling charge, which ejects the smoke canisters from the base of the shell. The canisters fall to the ground and emit their smoke in thin streams. The smoke streams travel an appreciable distance and then billow out.

f. Shell WP, Fuze Quick. A fuze quick WP shell burst is characterized by a fountain of brilliant white smoke and burning phosphorus. Small particles of phosphorus are spread upward and outward as a pillar of smoke forms and rises.

165. Effects of High-Explosive Projectiles

The effect obtained with an HE projectile depends on the fuze action (fig. 55). (For a detailed discussion of the effect of HE projectiles, see ch. 30.)

a. Fuze VT. VT Fuze is a radio-activated fuze which bursts the projectile automatically at a predetermined height above the earth's surface. Therefore, a height of burst adjustment is not required. During the adjustment, fuze quick is normally employed to obtain greater speed and to facilitate sensings. Fuze VT is suitable for use against—

- (1) Personnel in the open.
- (2) Personnel in entrenchments.
- (3) Area targets where neutralization is desired.

b. Fuze Time. Time fuze bursts the projectile on operation of a preset time mechanism or on impact. Height of burst is controlled by the observer. Since the observer must adjust the height of burst, use of this fuze is more time-consuming than fuze VT. However, with fuze time the observer may obtain any height of burst desired. Fuze time is ineffective in high-angle fire, because of the large height of burst probable error involved in long times of flight. Fuze time is suitable for use against the same types of targets as those against which fuze VT is used, within the limits imposed by the vertical probable error of the fuze.

c. Fuze Delay. When delay action of the fuze is used, the projectile has time after impact and before detonation (fuze M51A5, delay element is 0.05 second) either to penetrate and produce mine action or to ricochet and produce a low air burst. Fuze delay is used with shell HE for destruction missions which require penetration and for ricochet fire.

- (1) Factors which determine whether a shell will ricochet are angle of impact; shape, weight, and terminal velocity of projectile; length of delay of fuze;

and condition of surface of ground, including composition of soil.

- (2) When the angle of impact is small, the projectile tends to ricochet. As the angle of impact increases, the projectile first penetrates and then tends to rise. When the angle of impact is large, the projectile continues downward until it stops or detonates. When penetration occurs, a crater is produced. However, if penetration is very great, the burst may produce a camouflet; that is, a hole underground, the surface of the ground remaining unbroken. Whether a camouflet or a crater is produced depends on the depth of burst, type of soil, and force of detonation.
- (3) When penetration occurs and the shell is in the earth at the instant of detonation, fragmentation effect above the ground is very small. Penetration into a bunker or dugout will produce casualties by blast effect and fragmentation. Penetration into a structure built of logs, sandbags, or similar materials results in the blowing apart of constituent units. Effectiveness depends on the amount of high-explosive filler. Use of concrete-piercing (CP) fuze increases depth of penetration and the angle at which penetration may be obtained against reinforced concrete or heavy masonry targets.
- (4) Ricochet fire should be used *only* against personnel dug in or under light cover when VT or time fuzes are not available. Ricochet fire is not as effective as VT or time fuzes against targets requiring air bursts. Ricochet fire is not used against troops in the open. Against troops prone in the open, it would require ricochet action from approximately 80 percent of the rounds fired to be as effective as the same number of rounds fired with fuze quick. Factors which determine whether a projectile will ricochet cannot be evaluated for a particular point of impact until the bursts are sensed. Ricochet fire must be observed. An-

other fuze must be used if ricochet action cannot be expected from at least 50 percent of the rounds fired in fire for effect.

d. Fuze Quick. Quick (superquick) fuze action bursts the projectile immediately on impact. Ease of spotting a fuze-quick burst, together with the fact that no height of burst adjustment is necessary, makes possible a rapid adjustment. Fuze quick is suitable for use against—

- (1) Personnel in open (very effective in high-angle fire).
- (2) Personnel in sparsely wooded terrain where tree bursts give the effect of a low air burst.
- (3) Materiel, when penetration is not required.
- (4) Armored vehicles when firing heavy artillery (concussion).

e. Combined Fuze Action in Fire for Effect. When the target is such that more than one type of fuze action will add to the effectiveness of fire for effect, the observer will include the fuzes desired in the initial or a subsequent fire request.

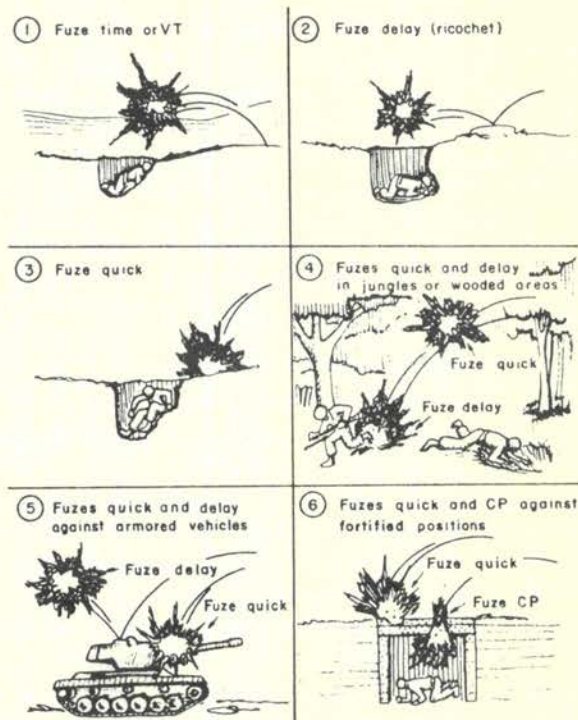


Figure 55. Effects of high explosive bursts.

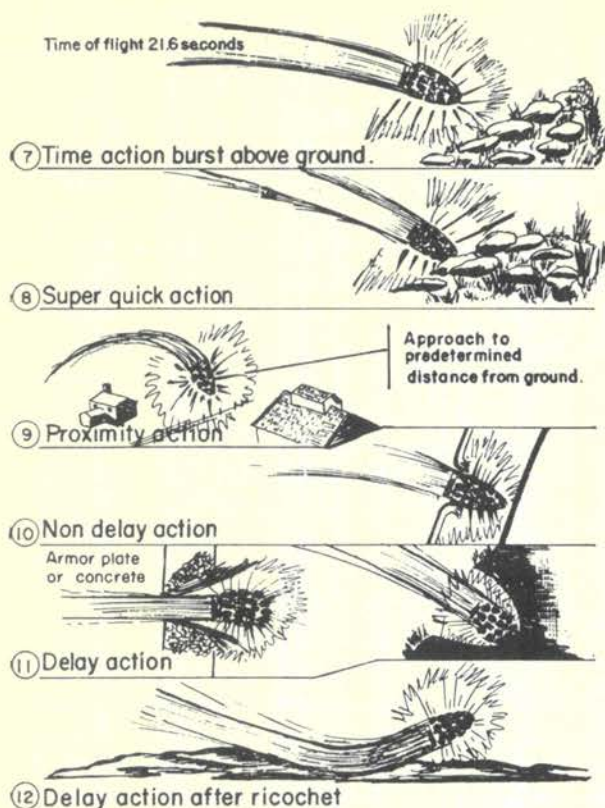


Figure 55—Continued.

166. Sensings

Determination by the observer of the location of a burst or group of bursts with respect to the adjusting point as observed along the OT line is called a sensing. Sensings are made for height of burst, range, and deviation. Except as noted in *b* below, bursts must be seen to be sensed. Sensings must be based on what the observer sees at

the instant the burst occurs. Sensings are made immediately after the burst occurs except when delayed to take advantage of drifting smoke or dust.

a. The observer should be required to announce his sensings during his early training. As an observer gains experience, sensings need not be announced.

b. Under certain conditions the observer may be able to make a sensing, even though he is unable to observe the burst. For example, if the observer heard the burst and the only possible place where the burst could occur and not be visible to the observer was in a ravine beyond the adjusting point, then the burst could be properly sensed as being beyond the adjusting point.

c. If visibility is temporarily impaired or if the observer is unable to obtain a sensing for a particular round, he reports UNOBSERVED, REPEAT RANGE.

167. Corrections

The observer causes the mean point of impact or burst to be placed on, or sufficiently close to, the target by making appropriate corrections during the adjustment. From his sensings, the observer determines deviation, height of burst, and range corrections in meters. He announces these corrections in that sequence as commands to bring the bursts onto the OT line, to obtain the desired height of burst (time fire), and to establish the appropriate bracket of the adjusting point along the OT line.

Section II. ADJUSTMENT OF DEVIATION

168. Deviation Sensings

a. Deviation is the lateral distance from the burst center to the OT line. A deviation sensing is the angular amount and direction of the deviation. During conduct of fire, the observer measures, in mils, the angular amount from the center of each burst or group of bursts to the OT line (fig. 56).

b. A burst, or the center of a group of bursts, may be on the OT line or it may be right or left of the OT line. Possible deviation sensings are LINE or (so much) RIGHT (LEFT). For ex-

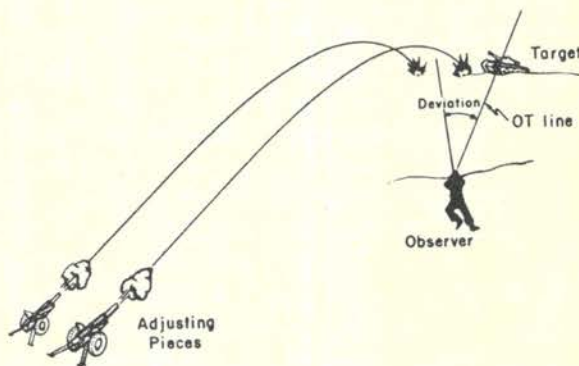


Figure 56. Deviation.

ample, the observer sees a burst which he measures to be 20 mils to the right of the OT line. His deviation sensing in this instance would be 20 RIGHT.

169. Deviation Corrections

a. *General.* A deviation correction is the distance in meters perpendicular to the OT line required to move a subsequent group of bursts to the OT line. It is particularly important in a precision mission that subsequent bursts be brought to the line as quickly as possible to facilitate FDC sensings during the adjustment. In area fire, minor deviations may be ignored if range sensings can be obtained.

b. *The OT Factor.* The number expressing observer-to-target (OT) distance in thousands of meters is called the OT factor. An OT factor of 3.7 represents an OT distance of 3,700 meters.

c. *Computation of Deviation Correction.* The observer uses the mil relation to compute a deviation correction. He multiplies the observed deviation in mils (deviation sensing) by the OT factor to obtain the required correction in meters. This amount is rounded to the nearest 10 meters. The correction is given in the direction opposite the sensing. Deviation correction is announced in meters as LEFT (RIGHT) (so much). The following are examples of computations of deviation corrections:

OT distance	OT factor	Sensing	Deviation correction
4,000 meters	4	40R	LEFT 160
3,400 meters	3.4	50L	RIGHT 170
2,500 meters	2.5	100L	RIGHT 250
1,500 meters	1.5	20R	LEFT 30

d. *Rounding Off OT Factor and Measured Deviation.* It is not always practicable to use the full OT factor and the exact measured deviation in computing each deviation correction. The observer strives to make the most accurate corrections possible; however, time limitations and the nature and size of the target often require that these figures be rounded off in computing a correction.

e. *Correcting Erroneous OT Factor.* During the adjustment, the observer may find that his initial estimate of the OT distance was in error. In such a case, he must adjust the OT factor in accordance with new indications of the OT

distance. For example, the observer's initial estimate of OT distance was 2,200 meters:

- (1) If, after the first volley he added 800 meters and then 400 meters more to obtain an OVER, it is apparent that the OT distance is between 3,000 and 3,400 meters; the OT factor should be increased accordingly to 3.2.
- (2) If, after the first volley, the observer made a deviation sensing of 70 RIGHT and a correction of LEFT 150, and the second volley as sensed 20 LEFT, the OT factor should be corrected. A correction of LEFT 150 has resulted in an angular change of 90 mils (70 mils right to 20 mils left). Using the mil relation formula, a new OT factor 1.7 is computed

$$(R = \frac{W}{m} \text{ or } R = \frac{150}{90} = 1.67).$$

Before changing the OT factor if the angle T is large (f below), care must be taken to distinguish range dispersion from deviation.

f. *Effect of Large Angle T.* The angle T is the angle at the target formed between the OT line and the gun-target (GT) line (fig. 57). When the angle T is large (500 mils or greater), range dispersion appears to the observer as deviations from the OT line, making line shots difficult to obtain. The observer must take advantage of accurate terrain sensings whenever possible. An observer must learn to judge whether or not small deviations from the OT line are due to range dispersion. In figure 58, the two volleys shown were fired at the same elevation and deflection. The difference in location of the bursts is due to range dispersion along the GT line. As viewed by observer 1, from whose location the angle T is relatively small, there appears to be little difference in the amount of deviation correction needed to bring these volleys to the OT line. However, as viewed by observer 2, volley 2 appears to be twice as far off the OT line as volley 1. To assist the observer in judging dispersion, the FDC personnel will announce to the observer the size of the angle T to the nearest 100 mils when the angle T is 500 mils or greater. When an observer finds that a deviation correction causes the next volley to burst on the opposite side of

the OT line at a sufficient deviation to make the sensing for range difficult, the observer should systematically reduce the size of subsequent deviation corrections until deviations become small enough to ignore. A guide to use is one-half the indicated correction (compute the correction in the usual manner, and then apply one-half of it). The cause of this deviation may

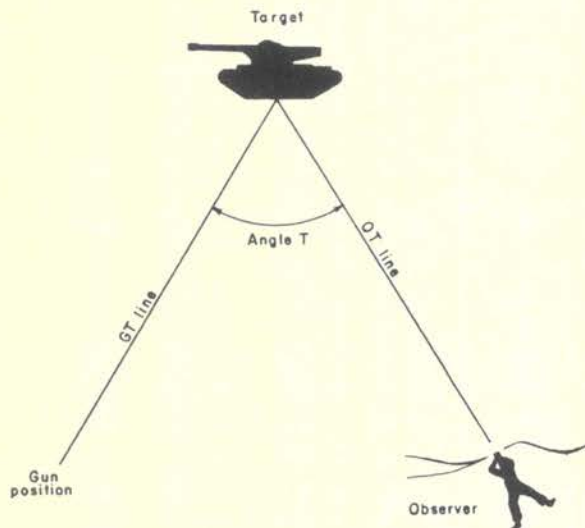


Figure 57. Angle T.

Section III. ADJUSTMENT OF HEIGHT OF BURST

170. General

In firing time fuze in area fire, the observer must adjust the height of burst. During adjustment, the observer senses height of burst and then determines and announces a correction to the nearest 5 meters as UP (DOWN) (so much) to raise or lower the subsequent burst to the desired height. Computations are made by using the mil relation in the same manner as for deviation shift. A good height of burst for adjustment is that height in the air which provides distinct sensings in range from the effect on the ground. The proper height of burst for fire for effect is 20 meters. Fuze action is sensed when fuze delay is being used for ricochet fire, although no corrections for height of burst can be made. When VT fuze is used, only malfunctions or graze bursts are reported. No height of burst sensings are made for an impact fuze.

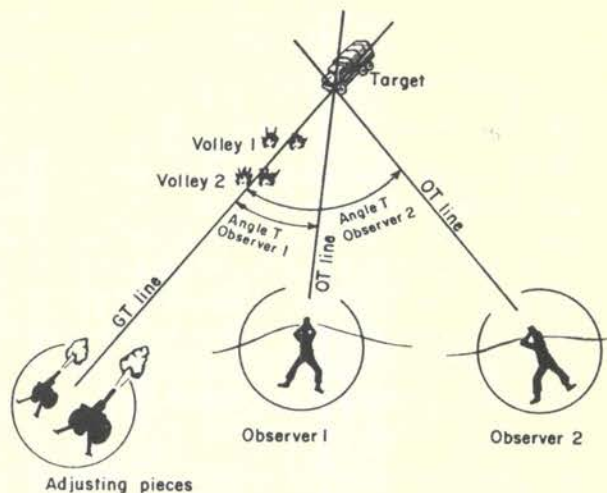


Figure 58. The effect of angle T when viewing range dispersion.

be range dispersion, irregular terrain, unrefined OT factor, errors of personnel or material, or a combination of all these factors.

g. Firing Close to Friendly Troops. The observer must exercise caution in making deviation corrections in the direction of friendly elements close to the target.

171. Height of Burst Sensing and Corrections

Height of burst sensings and appropriate corrections based on those sensings for fuze time are as follows:

a. Air. A burst or group of bursts in the air is sensed as AIR. The height of burst is determined by measuring the vertical angle between the target and the burst or center of the group of bursts and then multiplying the vertical angle by the OT factor. The height of burst thus determined is compared with the desired height of burst in order to compute the correction.

Example: OT factor is 3.0. The observer measures the vertical angle from the target to the burst to be plus 20 mils. The height of burst is then 60 meters above the target ($W = R \times \eta = 3.0 \times 20$). The correction is DOWN 40 (the desired height of burst is 20 meters, and the 60 meters is 40 meters above the desired height of burst).

b. Air Below. If the terrain is irregular, an air burst may occur below the level of the target. Such a burst is sensed as AIR BELOW and a correction for height of burst must be made. The correction is determined by using the procedure described in *a* above.

Example: OT factor is 3.0. The observer measures the vertical angle from target to burst as minus 10 mils. The height of burst is 30 meters below the target ($W = 3.0 \times 10$). The correction is UP 50 (30 meters to the height of the target plus 20 meters to the correct height of burst) (1, fig. 59).

c. Graze. If all the bursts of a salvo or volley occur on impact, the sensing is GRAZE. If there have been no previous air bursts during the adjustment, a correction of UP 40 should be given. When air bursts have occurred during the adjustment, the correction is UP 20.

d. Graze Above. In irregular terrain, an impact burst may occur above the target. In such a case the sensing of GRAZE ABOVE and no correction for height of burst is made (2, fig. 59).

e. Mixed. A salvo or volley resulting in an equal number of air and graze bursts is sensed MIXED. The correction is UP 20. However, under certain conditions, the observer may not wish to correct height of burst after a mixed sensing (par. 172).

f. Mixed Air. A salvo or volley resulting in both air and graze bursts is sensed MIXED AIR when the majority of the bursts are air bursts. No height of burst correction is made.

g. Mixed Graze. A salvo or volley resulting in both air and graze bursts is sensed MIXED GRAZE, when the majority of the bursts are graze bursts. The correction is UP 20.

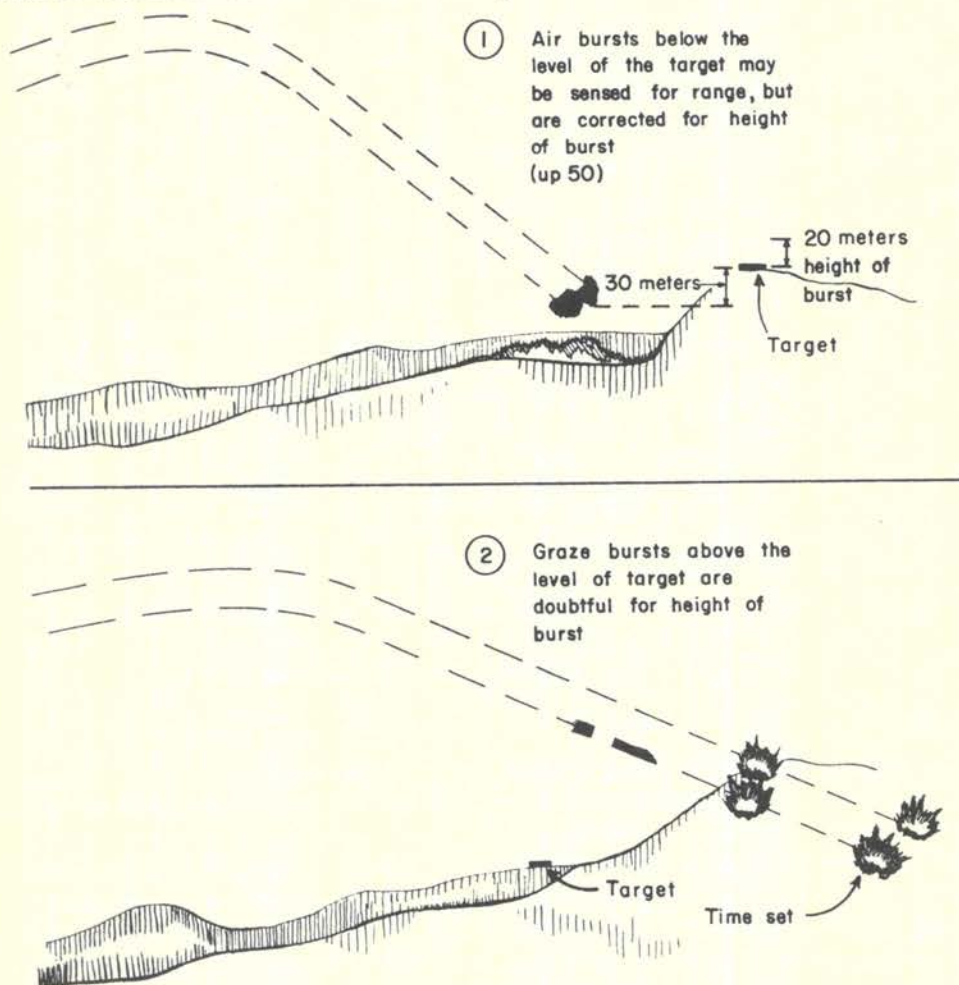


Figure 59. Sensing height of burst when firing on steep slope.

172. Height of Burst During Adjustment

a. When rounds cannot be sensed by the effect pattern of the air bursts on the ground because of heavy foliage, snow, or wet ground, adjustment is made with a very low height of burst (0 to 10 meters). Adjustment is not conducted with a mean height of burst lower than zero (graze and mixed graze have a mean height of burst lower than zero). However, at least one volley or salvo with all air bursts should be obtained as early as possible during the adjustment.

b. Fire for effect is entered only when a correct height of burst (20 meters) is assured, regardless of the existing range bracket. Fire for effect is *never* begun when the last salvo or volley observed resulted in all graze bursts.

173. Fuze Delay

When fuze delay is employed for ricochet action, no adjustment of height of burst is possible. The observer notes the number of air and graze bursts in each volley. If the two volleys which establish the bracket to be split to enter fire for effect or a volley which bracketed the adjusting point contained 50 percent or more air bursts, fire for effect is begun with fuze delay. If more than 50 percent of the bursts were sensed graze, the observer requests either FUZE VT or FUZE QUICK, whichever is more appropriate.

174. Fuze VT

No adjustment of height or burst is possible with fuze VT. The height of burst is influenced by the angle of fall of the projectile; the greater the angle of fall, the lower the height of burst (fig. 60).

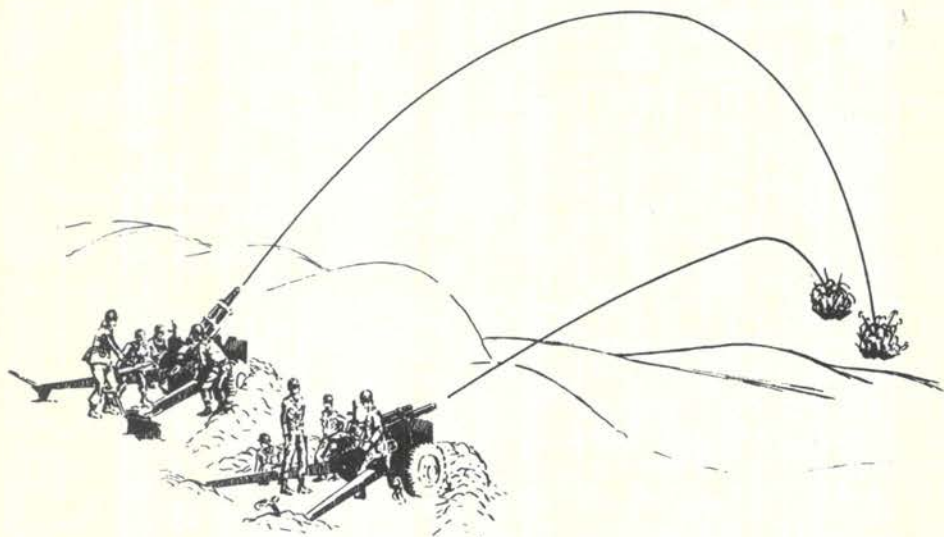


Figure 60. Effect of angle of fall on VT fuze.

Section IV. ADJUSTMENT OF RANGE

175. General

The observer usually makes an adjustment of range along the OT line by using the bracketing method of adjustment. The bracketing method of adjustment requires that the observer establish a range bracket early in the adjustment (par. 163) and then successively decrease the size of the bracket until it is appropriate to enter fire for effect.

176. Range Sensings

a. General.

- (1) Positive range sensings are required to make a proper range adjustment. The observer makes a positive range sensing before making a range correction. A burst or group of bursts on the OT line normally gives a positive range sensing. Figure 61 is in-

tended as a guide in which areas for the various sensings are approximated.

- (2) A positive range sensing by the observer of a burst not on the OT line is called a terrain sensing. Such a sensing is based on the observer's knowledge of the terrain, together with his observation of the burst, drifting smoke, or burst shadow. Even the experienced observer must exercise caution and good judgment in making terrain sensings. When sensings are made on drifting smoke or on shadows, direction of the wind and position of the sun must be considered (e.g., of the sun is at the observer's back, and the burst shadow falls on terrain short of the target, the burst may be sensed as SHORT).
- (3) Sensings of air bursts for range are based on the location of the bursts fragmentation pattern on the ground.

b. *Range Sensings.* Range sensings are as follows:

- (1) *Over.* Bursts which appear beyond the adjusting point are sensed OVER.
- (2) *Short.* Bursts which appear between the observer and the adjusting point are sensed SHORT *except* that if a fuze time graze burst occurs short and within 200 meters of the target, it is sensed DOUBTFUL (fig. 62).
- (3) *Target.* An impact burst which hits the target is sensed as TARGET. This sensing is used in *precision fire only*.
- (4) *Range correct.* A burst which is at the proper range or a volley or salvo resulting in an even number of overs and shorts is sensed RANGE CORRECT (this sensing is not used in the fire-for-effect phase of a precision mission).
- (5) *Doubtful.* A burst which can be observed but cannot be sensed for range as over, short, target, or range correct is sensed as DOUBTFUL.
- (6) *Lost.* A burst is sensed LOST when its location cannot be determined. Bursts which are sensed LOST must

be so reported to the FDC and a bold shift in deviation or range should be made.

- (7) *Lost over* (short). A burst which is not observed but is known to be definitely beyond or short of the adjusting point is sensed as LOST OVER or LOST SHORT.

177. Bracketing

a. In conducting an adjustment on a target, the observer should establish a range bracket as early in the adjustment as possible. When the first positive range sensing is made, the observer should make a range correction that can be expected to result in a range sensing opposite to the first sensing (e.g., if the first positive range sensing is SHORT, the observer should add enough to obtain OVER on the next round or group of rounds). As a guide, after the first positive range sensing, a range change of 400 meters is suggested if the initial target location is estimated, or 200 meters is suggested if the initial target location is surveyed data. (The above figures are guides only. In the final analysis, the observer must base his correction on his estimation of the location of the bursts (*c* below)).

b. After establishing a range bracket, the observer will successively split the existing bracket until it is appropriate to fire for effect.

c. The procedures described above are not to be considered inflexible. The observer must use his knowledge of the terrain, general experience, knowledge gained from previous firing, and his own judgment to determine the size of his range change. Even after the initial range bracket has been established, it is still essential that the observer exercise good judgment rather than automatically split the bracket. For example, if the observer adds 1,600 after an initial range sensing of SHORT and the second range sensing is OVER but the burst is much closer to the adjusting point than the initial volley, a range change of DROP 400 would be appropriate.

d. When the observer requests an adjustment on a target close to friendly elements, the necessary precautions are taken at the FDC to have the initial burst occur at a safe distance from

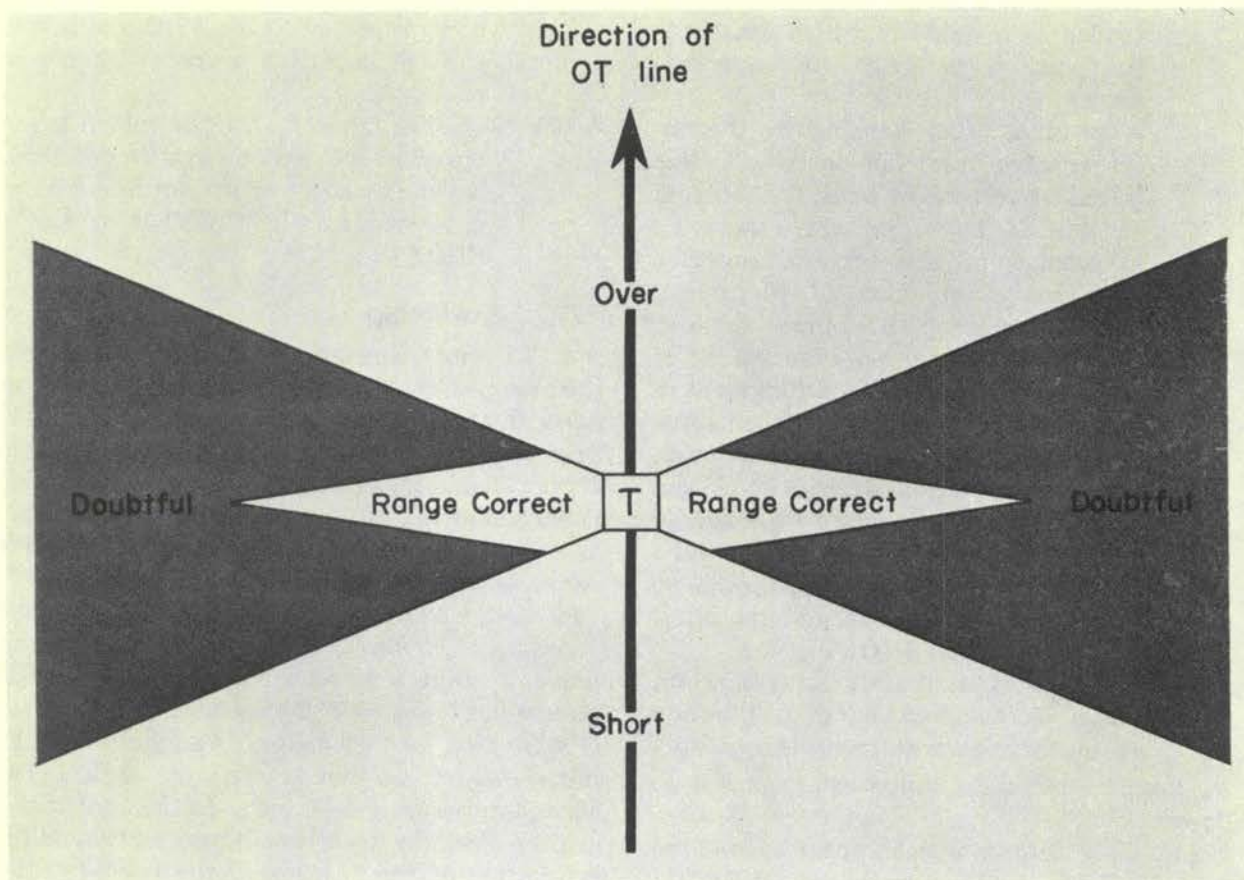


Figure 61. Range sensings.

In time fire, the observer should sense an impact burst short of the target as "graze doubtful" because he cannot tell where the burst would be if it were raised to air.

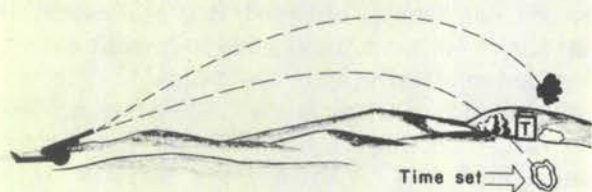


Figure 62. Error in site causing a round to fall short of the target in time area fire. With proper site, burst would be over.

friendly elements. Thereafter, the observer makes range corrections toward friendly elements in increments which he considers safe.

He does not necessarily attempt to bracket the target with any successive corrections. As his corrections bring the bursts closer to the target, positive range sensings can be made easily. Small, safe shifts may result in a greater expenditure of ammunition and time than normal bracketing methods but may be necessary to insure safety (fig. 63). An adjustment made in this manner is referred to as "creeping."

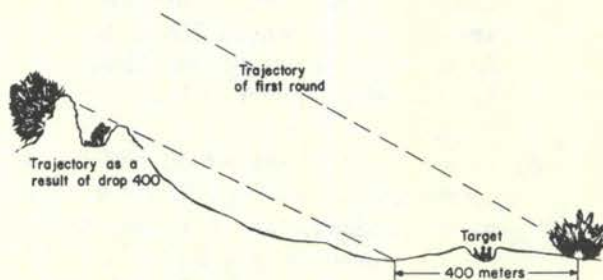


Figure 63. Need for creeping when close to friendly troops.

Section V. SUBSEQUENT FIRE REQUESTS

178. General

After the initial burst(s) appears, the observer transmits subsequent fire requests until the fire mission is completed. These requests include appropriate changes in elements previously transmitted and the necessary corrections for deviation, height of burst, and range. A subsequent fire request always includes a correction for range or a statement that no correction in range is desired. Any other element listed below, for which a change or correction is not desired, is omitted. The elements of subsequent fire requests, listed in the order announced, are as follow:

- a. OT azimuth.
- b. Deviation.
- c. Height of burst.
- d. Trajectory.
- e. Method of fire.
- f. Distribution.
- g. Shell.
- h. Fuze.
- i. Range.
- j. Control.

179. Change in OT Azimuth

A change in OT azimuth is given when it deviates from the announced azimuth by more than 100 mils. For example, an observer has begun an adjustment on several self-propelled guns, using a tree at azimuth 5620 as the adjusting point. During the adjustment, the self-propelled guns move to a new position an appreciable distance from the original adjusting point. The observer selects a new adjusting point in the vicinity of the target and measures the azimuth to the point as 5840. The first element of his next adjustment correction is AZIMUTH 5840.

180. Correction for Deviation

The observer determines and transmits deviation corrections to the nearest 10 meters as RIGHT (LEFT) (so much).

181. Correction for Height of Burst

The observer determines height of burst and transmits corrections to the nearest 5 meters as UP (DOWN) (so much).

182. Change in Trajectory

The observer requests a change in the trajectory during a low-angle adjustment when it becomes apparent that high-angle fire will be necessary or, during a high-angle adjustment, when it becomes apparent that high-angle fire is no longer required. For example, the observer is making an adjustment on a moving armored personnel carrier. During adjustment, the target moves into a deep gully for cover. The observer knows from previous firing in the area that high-angle fire will be necessary to bring effective fire into the gully, so he requests HIGH ANGLE. Conversely, an observer is making a high-angle adjustment on a column of vehicles halted along a street in a town constructed of tall buildings. During adjustment, the vehicles move out toward the edge of town. As soon as he notices that the vehicles are emerging from town, the observer should request LOW ANGLE to expedite the firing.

183. Change in Method of Fire

If a change in method of fire is desired during an adjustment, the observer announces the change. For example, in order to change volley fire to a salvo in which the pieces will fire in order from left to right, the observer requests SALVO LEFT. This change may be requested to take advantage of firing smoke or to clarify sensings when one round is obscuring another.

184. Change in Distribution

Since the S3 normally directs the firing of parallel (normal) sheaf in area fire adjustment, the observer seldom has reason to request a change in distribution during the adjustment phase. However, when the distribution is obviously in error or should be changed to facilitate the adjustment or increase effect, the observer reports this fact to the fire direction center. The FDC will then determine necessary corrections or cause the errors to be corrected. In order to bring more effective fire to bear on the target, the observer may request a change in distribution on entering fire for effect or after the first volley in fire for effect. To fit the sheaf to the width of the target, the observer

must specify the width of the sheaf; e. g., SHEAF 50 METERS. More rarely, if the shape of the target is such that special corrections must be applied to obtain the desired effect, the observer describes the shape of the target to the FDC so that appropriate corrections may be applied.

185. Change in Type of Shell

When the observer desires to change the type of shell, he announces the desired change as SHELL (such and such).

186. Change in Fuze

When the observer desires to change the fuze or fuze action, he announces the desired change as FUZE (such and such).

187. Correction for Range

The observer always announces a range correction or REPEAT RANGE as part of his subsequent fire request.

a. Add. The term "add" is used by the observer to move subsequent bursts away from the observer along or parallel to the OT line.

If a volley falls short of the target, the observer commands ADD (so much).

b. Drop. The term "drop" is used by the observer to move subsequent bursts toward the observer along or parallel to the OT line. If a volley falls beyond the target, the observer commands DROP (so much).

c. Repeat Range. The term "repeat range" is used by the observer when he does not desire a change in range. If a volley is sensed as DOUBTFUL for range, the observer commands a shift for deviation, followed by the command REPEAT RANGE. If the sensing is TARGET or RANGE CORRECT, REPEAT RANGE is appropriate.

188. Change in Control

When the observer desires to change the method of control, he announces the desired method of control.

189. Correction of Errors

If the observer discovers any error or omission in the transmission of a subsequent fire request, he corrects the error as outlined in paragraph 160.

CHAPTER 11

FIRE FOR EFFECT

Section I. PRECISION FIRE

190. General

The adjustment in precision fire is conducted with a single piece. The object of adjustment is to obtain a trial range. The trial range is the range at which fire for effect is begun. (See ch. 18 for FDC procedures.)

a. The observer requests fire for effect on splitting the appropriate range bracket, on obtaining a range correct sensing, or a target sensing. The appropriate range bracket to be split on entering fire for effect is usually 100 meters. However, when the range probable **error of the weapon is 38 meters or larger**, an observer will call for fire for effect when a 200-meter bracket is split. When such an occasion arises, FDC personnel will notify the observer.

b. Fire for effect consists of a number of rounds fired either singly or in groups of two or three by the adjusting piece. FDC informs the observer of the number of rounds that are to be fired in the initial group and in subsequent groups, if a change is to be made in the number of rounds to be fired. The observer normally does not send corrections during fire for effect. In a precision mission he only announces his sensings of bursts as they occur.

c. The observer should report to FDC the magnitude of the deviation and range error for a particular burst when, in the observer's judgment, the burst is the result of an error and information with respect to the location of the burst will assist the fire direction center. For example, a round in fire for effect is observed to be doubtful for range and 100 meters left of the registration point. The observer would transmit a sensing of DOUBTFUL, 100 METERS LEFT. Since sensings are normally made in mils, the word meters is used to prevent any misunderstanding. The error is reported in meters because the OT distance is not normally known at fire direction center. When a burst occurs very close to the registration point (target), the sensing may be made in meters to assist the FDC in improving deflection or in establishing that deflection is correct.

191. Precision Registration With Fuze Quick

a. During fire for effect in a precision registration with fuze quick, the observer announces the range and deviation sensing of each burst as he observes it. He announces range sensings as OVER, SHORT, DOUBTFUL, or TARGET and deviation sensings as RIGHT, LEFT, or LINE. The magnitude of the deviation is not announced. These sensings are announced in the order of range, and then deviation.

b. Fire for effect is continued until the FDC personnel notify the observer that the registration is complete.

192. Precision Registration With Time Fuze

a. After a fuze quick registration, a time registration may be initiated from the fire direction center. The FDC personnel notify the observer to OBSERVE TIME REGISTRATION. A round is fired at the adjusted deflection and elevation determined from the fuze quick registration and with a fuze setting determined at the fire direction center.

b. The observer normally does not send corrections in a time registration but only announces the height of burst sensing of each burst as AIR or GRAZE. However, if the height of burst of any round of a time registration appears to be in excess of 50 meters, the height of burst will be computed rapidly and if in excess of 50 meters, reported with the sensing; e.g., AIR, 75 METERS. If any round, in the judgment of the observer, is obviously in error for range or deflection, the amount of the error must be determined and reported with the sensing. For example, a round in fire for effect is observed to be a graze, on line with target, but estimated to be 100 meters short of the target. The observer transmits GRAZE, 100 METERS SHORT, LINE. Rounds are fired singly until both an air burst and a graze burst have been obtained. The FDC then will begin fire for effect. The observer will continue to sense each round as AIR or GRAZE. He must note whether the airbursts are high (over 15

meters) or low, but he does not report this information unless it is requested by fire direction center. The time registration is continued until terminated by fire direction center.

c. For an example of a precision registration, see paragraph 237.

193. Destruction Mission

a. In a destruction mission, FDC will direct the use of fuze quick in the initial rounds of fire for effect, as well as adjustment. This procedure facilitates valid sensings by the observer and expedites determination of an adjusted de-

flection and quadrant elevation at the fire direction center. Subsequently, the S3 directs the use of the fuze that will be most effective against the target; e.g., fuze delay, fuze concrete-piercing, etc. If this subsequent fuze is not effective, the observer must request a change to a fuze which, in his opinion, will be more effective.

b. During fire for effect, the observer announces sensings just as he does in a precision registration with fuze quick.

c. Fire for effect is continued until the observer notifies the FDC that the mission has been accomplished.

Section II. AREA FIRE

194. General

a. In area fire, the observer requests fire for effect in the initial fire request when his target location is accurate enough to preclude the need for adjustment. Normally, the observer requests fire for effect at the conclusion of an adjustment.

b. The type and the volume of fire delivered in fire for effect are determined by the S3. His decision is based on the observer's description of the target, the effect sought, status of ammunition supply, and other considerations (ch. 30). If fire for effect is ineffective or insufficient, necessary corrections are made and additional fire for effect is requested.

c. On completion of fire for effect, the observer sends END OF MISSION and reports the effect observed.

195. Fire for Effect After Adjustment

a. *Deviation.* The adjustment of deviation is complete when the mean point of impact or burst is on the OT line. Since, during the adjustment, the observer sends successive deviation corrections to place the bursts on the OT line, it should not be necessary to make a large shift on entering fire for effect.

b. *Height of Burst.* When time fuze is being used, fire for effect is not requested until the height of burst is correct or until a correction can be expected to result in the correct height of burst. Fire for effect is not immediately requested if the last volley observed consisted entirely of graze bursts. The observer lacks information upon which to base a correction because the

height of burst of such a volley is an indeterminate amount below zero. When fuze delay is being used for ricochet fire, its use is continued on entering fire for effect only if at least 50 percent of the bursts which established the final range bracket were airbursts.

c. *Range.* The adjustment of range is complete when the observer has obtained bursts at the same range as the adjusting point (range correct) or when he has split the appropriate range bracket. When the target is fixed, of little depth, and clearly visible, or when the fires of more than one battery are to be massed on the target, it is appropriate to split a 100-meter range bracket. When the target is moving, has substantial depth, or is poorly defined, it may be appropriate to enter fire for effect on splitting a 200-meter range bracket. When the range probable error is **38 meters or larger**, the FDC will notify the observer to enter fire for effect on splitting a 200-meter range bracket.

196. Distribution

a. Normally, the S3 determines the proper distribution of fire for a target. His decision is based on the observer's description of the target and other available information. Unless the nature and the size of the target require otherwise, artillery fires are delivered at center range, with light and medium artillery using a parallel sheaf and heavy artillery using an open sheaf. In certain cases, the S3 may direct the use of a sheaf other than that normally fired. He also may

direct a battery or batteries to fire through different elevations for greater coverage.

b. When appropriate, the observer may request a particular sheaf. This request should be announced in the initial fire request when possible. It may be announced later if it becomes apparent that the sheaf being fired does not provide optimum distribution. In making such a request, the observer announces the type of sheaf desired; e.g., **OPEN SHEAF** or **SHEAF, 50 METERS**.

c. When the number of pieces allocated to the mission are not adequate to cover the target effectively with an open sheaf, the observer may make successive shifts in fire for effect to insure coverage of the target.

197. Surveillance of Fire for Effect

The observer carefully observes the results of the fire for effect and then takes whatever action is necessary to complete the mission.

a. If the fire has been effective and sufficient, the observer announces **END OF MISSION** and reports the effect observed; for example, **20 CASUALTIES, INFANTRY DISPERSED**. If he desires to make a correction to improve the accuracy of the replot of the target but not to

fire again, he announces the correction; e.g., **LEFT 20, REPEAT RANGE**, followed immediately by **END OF MISSION**.

b. If the fire has been insufficient but accurate, including an effective height of burst, the observer may request **REPEAT RANGE, REPEAT FIRE FOR EFFECT**, to obtain additional fire.

c. If any element of the adjustment (deviation, range, or height of burst) was sufficiently in error, so that the effect sought was not obtained, the observer should correct the element(s) in error and continue the fire for effect; for example, **DOWN 10, ADD 50, REPEAT FIRE FOR EFFECT**.

d. If ricochet action with fuze delay was indicated and sought but during fire for effect fewer than 50 percent of the bursts were airbursts, the observer requests a change to fuze VT or fuze quick and calls for additional fire, if needed; for example, **FUZE VT, REPEAT RANGE, REPEAT FIRE FOR EFFECT**.

e. If the observer desires that the target be replotted for future use, he announces **END OF MISSION**, reports the effect observed and adds **REQUEST REPLOT**.

f. For an example of an area mission, see paragraph 239.

CHAPTER 12

THE AIR OBSERVER

Section I. INTRODUCTION

198. General

Observation and adjustment of fires are extended and improved by proper use of organic Army aviation and high-performance aircraft. An air observer is normally employed since it is difficult for a pilot to navigate and observe at the same time. However, the pilot should be well trained in the adjustment of fire, since such knowledge is invaluable in training a new air observer and increases the flexibility in obtaining prompt and accurate fire if an observer is not available.

199. Observation From Army Aircraft

Observation from organic Army aircraft is normally limited to altitudes and locations which allow the aircraft to avoid enemy ground fire and enemy fighter aircraft.

200. Observation From High-Performance Aircraft

Use of high-performance aircraft provides observation deep into enemy territory beyond the limits of organic Army aircraft. The pilot and observer can fly over enemy territory to sufficient depth to observe and adjust long-range artillery fire. Usually two aircraft are used on a mission—one to adjust the fire and the other to observe for hostile aircraft. Danger from both hostile air defense artillery and hostile planes usually increases as the duration of the flight and the depth into hostile territory increases. For this reason the air observer must minimize the time required for an adjustment.

Section II. PREFLIGHT PREPARATIONS

201. General

The air observer and pilot should be given a preflight briefing by either the artillery support section commander or one of the unit staff officers. Preflight coordination with ground units should cover the method of calling for and executing flak suppression programs and the withholding of friendly aircraft and ground fire against friendly planes.

202. Preflight Briefing

a. All pilots and observers flying a mission should be briefed on all points pertinent to the mission, including—

- (1) Location of battery position areas, registration points, concentrations, known points, reference lines to be used in making corrections (if GT line is not used), suspected targets, and areas to be searched.

- (2) Tactical situation, to include locations of friendly troops and no-fire lines and zones of action of supported troops.
- (3) Surveillance required, time of mission, type of adjustment to be made, maps and photographs to be used, known enemy air defense, flight instructions, and security restrictions.
- (4) Communication details, to include location of ground radios and panel stations, channels to be used, call signs, check-in time(s), and prearranged signals.

b. All important enemy locations, lines, and areas discussed in the briefing are recorded on the appropriate map. Photographs, oblique or vertical, are gridded when possible and marked for direction and locations of critical points, lines, and areas.

Section III. DETERMINATION OF INITIAL DATA

203. General

The air observer must transmit his initial fire request in the same sequence as the ground observer. Most target locations are given as military grid references; other target locations are given in terms of a shift from a known point and a reference line. Since the plane is constantly moving, the observer-target line method is not applicable. Therefore, sensings are based on a given reference line instead of an observer-target line.

204. Determination of a Reference Line

The air observer makes sensings and corrections with respect to a reference line. The reference line and its direction must be known by the FDC personnel of the unit for which the observer is adjusting fires. If possible, the reference line is established prior to flight. There are three reference lines which the observer may select for use in making his adjustment—the gun-target (GT) line, a line of known direction, or a convenient line which the observer selects when in flight and describes in sufficient detail so that the FDC personnel can determine its direction. Since the observer is moving continuously, his reference line on the ground must be easily identified and distinctly visible. In addition, the observer should select a prominent terrain feature or object near the target to facilitate target identification at all times.

a. Gun-Target Line. The observer may select the GT line as his reference line. If the observer knows the location of the weapons, visualization of the GT line is facilitated. If he does not know the location of the weapons, the observer requests that two rounds (ranging rounds) be fired at different ranges but at the same deflection setting. By observing the two bursts, the observer determines the direction of the GT line. Once the observer determines the direction of the GT line, he should select terrain features, such as a road, stream, or ridgeline, which will assist him in remembering the GT direction.

b. A Line of Known Direction. The observer may select a line formed by a road, railroad,

canal, or any series of objects. Prior to flight the observer selects the line and determines its direction; he informs the FDC of this line and direction and that he will base his sensings and corrections on this line.

c. A Convenient Reference Line. While in flight, the air observer may select a reference line which is convenient and easily identifiable. To use this line, the observer must describe it in detail to the FDC personnel so that its direction may be determined. The FDC personnel confirm the location and direction of the line and then notify the observer to commence using it as his reference line.

205. Location of Targets

When a target is observed, its location can be determined and indicated by military grid reference, by a shift from a known point and a reference line, by a prearranged code, or by cardinal direction.

a. Military Grid Reference. The observer locates the target on his map and transmits the coordinates of the location.

b. Shift From a Known Point and a Reference Line. The observer may indicate the location of a target by announcing a shift from a known point and a reference line. The point must be plotted on the firing chart and must be identifiable on the ground by the observer. This point may be a registration point or any point previously located by survey or by firing. The observer announces the shift from the known point to the target in meters; e.g., FROM REGISTRATION POINT 1, RIGHT 400, ADD 800. If any reference line other than the GT line is used, it must be identified; e.g., FROM CONCENTRATION AB406, REFERENCE LINE NORTH-SOUTH HIGHWAY, RIGHT 400, ADD 800.

c. Prearranged Code. When the location of a target has been established by the FDC personnel and the observer prior to a flight, a code name or concentration number may be given to it. In this case, the observer need only transmit the preassigned symbol to obtain fire on the target.

d. Cardinal Direction. Cardinal points of the

compass may be used for locating targets from a reference point; for example, FROM REGISTRATION POINT 1, EAST 400, NORTH 800.

206. Determination of Distance

The observer can determine distance on the ground by requesting one round at a given range and then add or drop 400 (or more)

meters for a second round at the same deflection setting. A range spread of no less than 400 meters will allow accurate visualization of the GT line and minimize the effect of normal range dispersion. By using this method of determining distance, the observer establishes a "yardstick" for estimating subsequent range and deflection corrections.

Section IV. ADJUSTMENT PROCEDURE

207. General

Adjustment and adjustment procedures for the air observer are the same as for the ground observer *except* as noted in paragraph 203.

a. Considerations for the selection of an adjusting point are the same for both air and ground observers. When no maps are available and there has been no previous firing in an area, the observer may request a marking volley be fired in approximately the center of the zone of observation and at a range sufficient to clear friendly frontlines.

b. Opening fire, sensings, and corrections are the same for the air observer as for the ground observer *except* for those sensings and corrections noted in paragraph 208.

c. The air observer can adjust artillery fire in the dark by using daylight procedures. However, artificial illumination may be necessary to make the target area discernible. The illumination may be by searchlight, illuminating shells, or aircraft parachute flares. Aircraft parachute flares are considered the most desirable because of the length of burning time and the illumination produced. It is desirable that the aircraft flares be released from an aircraft other than the observer's aircraft. The observer may then see into the target area from the side rather than looking down into the area after a flare has been released. Night adjustment missions should be planned during daylight hours. Plans should include a daylight flight over the proposed area of operation for the selection of checkpoints and for general terrain orientation. The aerial observer must consider the different shapes and shadows which will be formed in the target area as a result of the illumination. Orientation may also be a problem, especially

on very dark nights. However, effective fire can be placed on the target area by a well-trained observer.

d. The air observer may use AT MY COMMAND during the adjustment phase so that the aircraft can be positioned for proper observation of each volley. The time of flight is sent to the observer following the announcement of ON THE WAY for the initial round(s). A new time of flight will be announced if the initial time changes more than 5 seconds. A 5-second SPLASH warning is transmitted from the FDC to the observer for each volley.

208. Adjustments

a. *Adjustment of Deviation.* The air observer senses deviation in meters, based on the GT line or other prearranged reference line, and corrections are announced in meters.

b. *Adjustment of Height of Burst.* The air observer is seldom required to adjust height of burst in area missions since differences in height are not readily apparent. The observer may be required to observe time registrations in which case sensings of AIR or GRAZE are transmitted.

c. *Adjustment of Range.* The air observer senses bursts for range, based on the GT line or other prearranged reference line, and, using the bracket method of adjustment, announces range corrections in meters.

209. Fire for Effect

The air observer calls for fire for effect and announces sensings during fire for effect in the same manner as that described for the ground observer (para. 195).

CHAPTER 13

ADJUSTMENT PROCEDURE FOR SPECIAL SITUATIONS

Section I. CONDUCT OF FIRE WITH CHEMICAL SHELL

210. General

Chemical shells include smoke shells (base ejection smoke shell and white phosphorus shell) and toxic chemical shells (irritant or lethal agents). For detailed uses of toxic chemical shells, see FM 3-5 and TM 3-200.

211. Smoke Shell

a. General. Smoke shells are used to screen enemy observation, to aid in the adjustment of fire (fire to help the observer locate his rounds), as a prearranged signal, and as a marking round for air observation or an air strike. Requests for smoke screens may sometimes be denied, since such missions must be coordinated with higher authority to avoid interference with other operations. (See ch. 25 for FDC procedures.)

b. Observer Procedure for Screening With Base Ejection Smoke Shell. When the observer wishes to screen an area with base ejection (BE) smoke shell, he normally selects an adjusting point well upwind from the area to be screened. The selection of the adjusting point is influenced by wind speed and direction and other climatic conditions. The adjustment is begun with shell HE and fuze quick to avoid obscuring the adjusting point (normal observer procedures apply). When shell HE has been adjusted to within 100 meters of the adjusting point, the observer will call for shell smoke to complete the adjustment. The adjustment is continued until the proper height of burst (approximately 100 meters) and placement of smoke are obtained. When the desired placement is obtained, the observer calls for fire for effect to build and maintain the smoke screen. The rate of fire necessary to maintain the screen depends on the width of front to be screened, the direction and speed of the wind, and the volume and density of smoke produced by each burst. The fire of a single piece, the continuous fire of several pieces, or volley fire may be used. When smoke is used to prevent enemy observation of the operations of friendly troops, the observer adjusting the fire

should be near the troops whose operations are to be concealed. The screen should be placed on or near enemy positions. Rounds of HE shell (preferably airbursts) or white phosphorus shell fired into the smoke area will prevent enemy troops from leaving shelter to extinguish the smoke canisters.

c. White Phosphorus Shell. White phosphorus (WP) shell is useful for marking, screening, incendiary, and casualty producing actions. The adjustment is made with shell HE and fuze quick. When the adjustment is complete, the observer will call for shell WP. Fuze quick is used with WP. Action of the fuze and burster charge breaks the shell and scatters phosphorus particles, which ignite spontaneously on contact with the air. The smoke rises rapidly because of the heat generated by the burning phosphorus. WP is desirable for marking purposes and for the buildup of a smoke screen, but, because of the rapid rise of the smoke, WP is not as effective as base ejection smoke for maintaining a smoke screen. When white phosphorus shells are used against frame houses or other objects of flammable material, some fuzes should be set at delay to effect penetration before bursting and thus increase the incendiary effect of the burning phosphorus particles. Casualties are effected by the small particles of phosphorus adhering to the clothing and skin, causing painful burns.

d. Colored Smoke. Base ejection smoke shell in colors (white, green, red, and yellow) is used for aiding an observer to locate his rounds, as a prearranged signal, and as marking rounds fired at a predesignated point to guide an airstrike to a target. See *b* above for adjustment procedure.

212. Toxic Chemical Shell

Toxic chemical shell is fired as authorized by higher authority. Wind speed and direction are always considered so that friendly troops are not unduly endangered. Data for firing toxic chemical

shells should be the most accurate obtainable. To achieve surprise, adjustment should be avoided if at all possible or conducted on an auxiliary adjusting point with HE. Either low air or super-

quick impact bursts are used with toxic chemical shells. Weather conditions in the zone of observation are determined by the movement of battle dust and smoke and reported to FDC (par. 444).

Section II. BATTLEFIELD ILLUMINATION

213. General

The purpose of battlefield illumination is to provide friendly forces with light to assist them in night ground operations, offensive or defensive. The artillery observer is concerned primarily with two means of illumination—illuminating shells and searchlights. When properly used, night illumination increases the morale of friendly forces, facilitates operations, and harasses and blinds the enemy. The artillery has the responsibility of providing illumination with illuminating shells and searchlights. Any artillery observer may be called on to conduct an illumination mission.

214. Conduct of Fire Using Illuminating Shell

a. Uses. Illuminating shell is used for the following purposes—

- (1) Illuminating areas of suspected enemy movements.
- (2) Night adjustment or surveillance of artillery fire by air or ground observer.
- (3) Harassing the enemy in positions or installations.
- (4) Furnishing direction to friendly troops for attacks or patrol activities. (Illumination flares must be placed well in advance of friendly troops to avoid illuminating the troops.)
- (5) Guiding low level tactical bombers on important targets within artillery range.

b. Ammunition. The following tabulation gives

some of the factors to be considered in the employment of artillery illuminating shells. Data are approximate.

Cannon	Initial height of burst	Distance between bursts (spread illumination)	Burning time	Rate of continuous illumination
105-mm	750	800	60	2 rounds per minute
how	meters	meters	seconds	
155-mm	750	800	60	2 rounds per minute
how	meters	meters	seconds	

c. Initial Fire Request. When the observer desires to illuminate the battlefields using illuminating shell, his initial fire request is made using the procedures described in chapters 8 and 9. Elements of the initial fire request that require special consideration are—

- (1) *Type of adjustment.* The size and shape of the area to be illuminated, OT distance, conditions of visibility, and candlepower of shell influence the selections of the type of adjustment. Following are the types of adjustment that may be used:
 - (a) *One gun.* One round from one gun.
 - (b) *Two guns.* One round from each of two guns bursting simultaneously at approximately the same point in the air.
 - (c) *Two guns, deflection spread.* One round from each of two guns bursting simultaneously at the same range but separated in deflection. (For distance between bursts, see *b*)

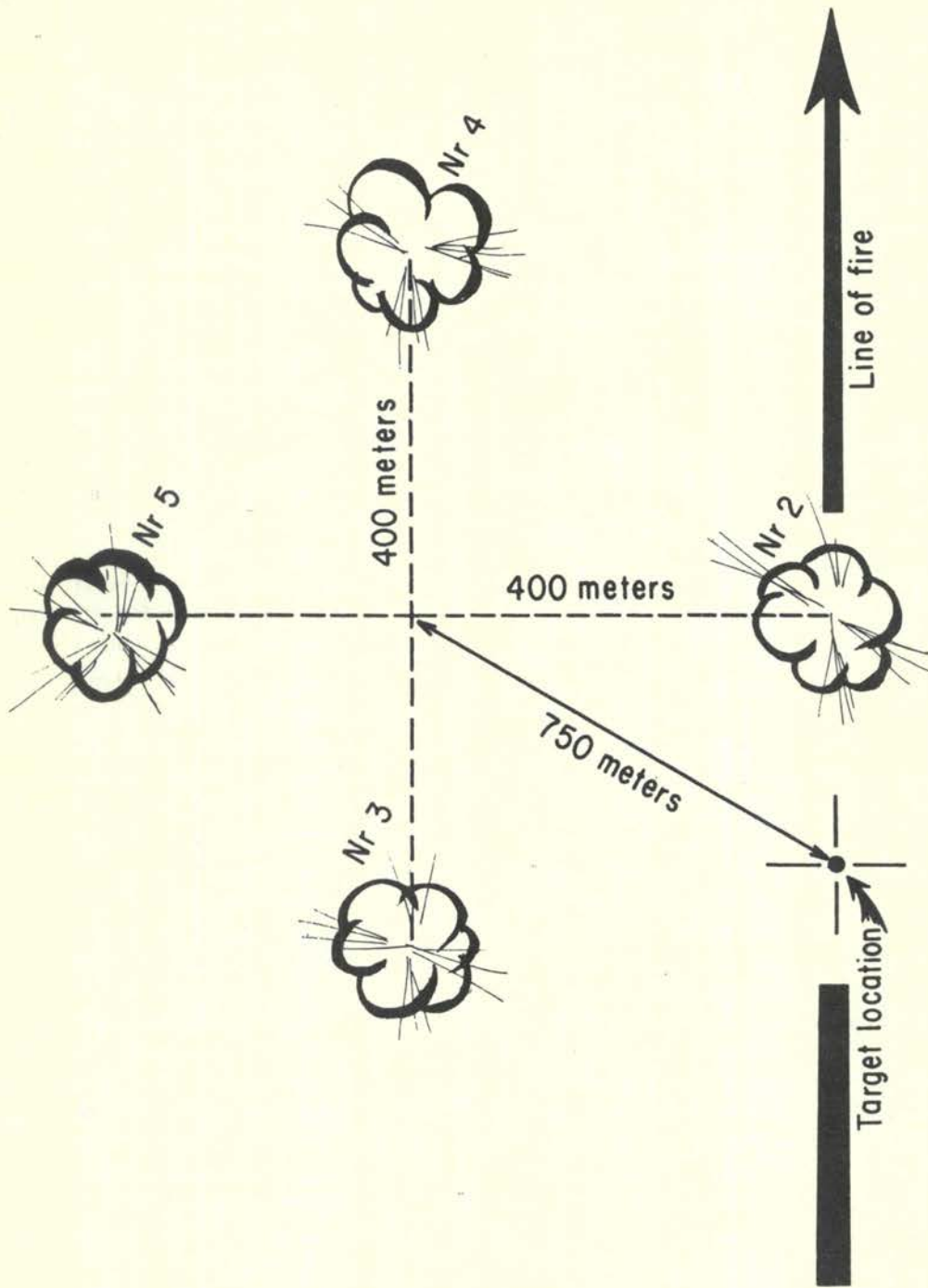


Figure 64. Artillery illuminating shell.

above.) (All spreads are made with respect to GT line.)

(d) *Two guns, range spread.* One round from each of two guns bursting simultaneously but at different ranges along the GT line. (For distance between bursts, see *b* above.)

(e) *Four guns.* One round from each of four guns bursting simultaneously in a diamond pattern (fig. 64).

(2) *Type of projectile.* ILLUMINATING must be specified.

(3) *Type of fuze.* Fuze time is used habitually with illuminating shell. Therefore, this element is omitted from the initial fire request.

d. *Adjustment.*

(1) Range and deviation are adjusted using standard observed fire procedures, except that the adjustment is considered complete when the illumination is within 200 meters of the desired location. Normally, range, height of burst, and deviation are adjusted concurrently. If the height of burst is drastically in error, it may be necessary to adjust height of burst before the other elements in order to have enough light to see the target.

(2) The correct relative position of the flare to the adjusting point depends on the terrain and the wind. Generally, the position of the flare should be to one flank of the adjusting point and at about the same range. In a strong wind, the point of burst will have to be some distance from the adjusting point because of drift of the flare. If the target is on a forward slope, the flare should be on the flank and at a slightly shorter range. If the adjusting point is a prominent target, better visibility may be obtained by placing the flare beyond the target to silhouette it.

(3) The proper height of burst is that which will allow the flare to strike the ground just as it stops burning. Changes in height of burst are made in multiples of 50 meters. The varia-

tion in the time of burning of flares renders useless any finer adjustment of the height of burst.

(4) When the point of burst is too high, the height of burst change is estimated from the height of the flare as it burned out. When the point of burst is too low, the change required is estimated from the length of time (T) in seconds the flare burned on the ground. By multiplying $T \times 10$ (approximate rate of descent, 10 meters per second), the observer can determine the approximate correction required.

Example: Flare burned 13 seconds on the ground; $13 \times 10 = 130$; correction is UP 150 (answer rounded off to nearest 50 meters).

(5) Once the observer has adjusted the illuminating shell to the desired location, he should control the rate of fire and number of pieces firing to reduce ammunition expenditure to the minimum necessary for the required observation.

e. *Illumination for HE Adjustment.*

(1) If the adjustment of illuminating shell discloses a suitable artillery target, the observer should request CONTINUOUS ILLUMINATION while he adjusts HE fire on the target.

(2) As soon as the observer has located a suitable target for HE fire, he should initiate a normal fire request. If no better means of designating the location of the target is possible, the burst center of the illumination can be used as a reference point. The OT azimuth is announced when it varies by more than 100 mils from the azimuth announced for illumination.

(3) If the observer decides to adjust both the illuminating fire and the HE fire concurrently, he prefaces the requests pertaining to illumination with the word ILLUMINATING and those pertaining to HE with the letters HE; for example, ILLUMINATING, ADD 200, HE, RIGHT 60, ADD 200.

- (4) If the HE adjustment is made on an immobile target, such as a disabled tank or a bridge under construction, the observer may be able to conserve illuminating ammunition by coordinating illumination with the adjustment of HE. The observer requests COORDINATED ILLUMINATION instead of continuous illumination and requests control to be BY SHELL, AT MY COMMAND. This indicates that both HE and illuminating shell will be fired only at the observer's command. As soon as FDC personnel report that illuminating and HE fires are ready, the observer commands the firing of illuminating shell and then gives the command to fire the HE shells, so that the rounds will arrive during the period of maximum illumination of the target.

f. *Example Mission.* See paragraph 240 for example mission.

215. Conduct of Fire Using Searchlight Illumination

a. The primary use of searchlights by the observer is to illuminate areas of suspected enemy movement and night adjustment or surveillance of artillery fire from air or ground observation posts. Searchlights are also used to guide friendly elements, mark bomblines, mark targets for close support air missions, and illuminate objectives in an attack.

b. The number of lights used in any mission will depend on the number available and the situation at that particular time. Normally, when direct illumination is used, a single light will suffice.

c. For the adjustment of the searchlight beam, the observer procedure is similar to that employed in a fire mission. However, the observer makes the adjustment on the searchlight-target line in deviation and site. The correction is made in one of two ways. The observer can move the beam in meters, right or left and up or down, or the observer can move the beam in a number of beam widths. In most cases, the beam-width method is simpler and faster for the observer, since his yardstick is the width

of the beam itself. The narrowest beam width (pencil beam) is 22 mils; when fully spread (spread beam), the beam width is 265 mils. Examples of observer corrections are—

- (1) RIGHT 100 or RIGHT TWO BEAMS.
- (2) UP 20 or UP ONE-HALF BEAM.

d. The smallest correction in meters which can be made by the observer is 20 meters. For beam widths, the smallest correction is a quarter beam width shift. It is not necessary to give a change in both deviation and elevation each time an adjustment is desired; it is necessary to give only the element to be corrected while the omission of the other element indicates it is to remain the same. If it is desirable to change the degree of beam spread, the terms used are INCREASE BEAM SPREAD (so much) or REDUCE BEAM SPREAD (so much). This correction precedes the elevation and deviation corrections.

e. Elements of the illumination request are as follows:

- (1) *Identification of observer.* Identification of the observer for an illumination mission is the same as that for a fire mission.

Warning. The warning for a searchlight mission is ILLUMINATION MISSION. Since this term is used only for a searchlight mission, it alerts all personnel involved to pass the mission to the searchlight light direction center (LDC). The LDC is normally located at division level. Operators in the communication network must be familiar with this warning signal and the action to be taken.

- (2) *Target location.* The target may be located by any of the methods described in chapter 8. In addition to being necessary in order to locate the target by polar coordinates and shift from a known point, the OT azimuth is used to aid the light direction center in the selection of a searchlight that will best illuminate the target.
- (3) *Nature of target.* Nature of the target is preceded by the word SUSPECTED if identity of the target cannot be made. If the target is identified, the

procedure is the same as that for a fire mission. This report will enable the LDC personnel to determine the priority of missions.

- (4) *Type of adjustment.* If the type of adjustment is omitted from the observer's request, the observer will receive one light in adjustment. The observer may request two or more lights if he desires.
- (5) *Type of illumination.* The observer may have a choice of direct or indirect illumination. Direct illumination requires a clear line of sight between the searchlight and the target. Visibility into the illuminated area is nearly equivalent to daylight observation if the light source is behind the observer. With a single beam shining at low angles of elevation, deep shadows are cast by brush and other small objects. Intersecting beams may be used to eliminate shadows in the immediate target area. Direct illumination eases control; it is, however, more vulnerable to enemy fire than indirect illumination. With direct illumination, there is a possibility of impairing the night vision of friendly forces and of silhouetting friendly troops and installations. The observer must try to avoid both of these situations. If the observer does not specify **INDIRECT ILLUMINATION**, it will indicate that he desires direct illumination. If **INDIRECT ILLUMINATION** is requested, the observer will receive light which utilizes the scattered or reflected light rays from the main searchlight beams. For an observer looking away from the light source, visibility in the illuminated area at ranges of 4,500 to 6,500 meters from the light source is equivalent to visibility under a quarter moon. The

diffused light of indirect illumination reaches into hollows, draws, and tree-lined roads. An observer in an area illuminated by diffused light can detect, with the unaided eye, a man standing at ranges up to 150 meters, and, with the aid of field glasses, he can detect a man moving at considerably greater ranges. Indirect illumination can be employed for longer periods of time than direct lighting because the light source is less vulnerable to enemy interference.

- (6) *Degree of beam spread.* Since the searchlight beam can be spread from 22 mils to 265 mils, the beam spread is included in the request so that the observer can illuminate as large an area as possible commensurate with his observing range capability. The degree of beam spread is designated as a fractional part of a fully spread beam in increments of one-eighth spread. If the observer omits this element, a pencil beam (22 mils) will be used.
- (7) *Control.* There are only two methods of control used with searchlights—**WILL ADJUST** and **AT MY COMMAND**. **FLICK** is the command used to turn on the lights. The observer uses the word "flick" to prevent personnel from misinterpreting fire commands.

f. Some of the terms used in an illumination mission but not otherwise common to field artillery are:

- (1) Flick—put light in action (corresponds to command **FIRE**).
- (2) Action complete—pointing data have been set on light (corresponds to command **ON THE WAY**).
- (3) Cut—put light out of action.
- (4) Hold—light is on target.

g. See paragraph 241 for example mission.

Section III. CONDUCT OF ASSAULT FIRE

216. General

a. Assault fire is a special technique of indirect fire. Firing is conducted at short range from a defiladed weapon position to attain pinpoint accuracy against a stationary target. The gun-target range is sufficiently short to make possible successive hits on the same portion of the target. Only one gun is used on a mission, and the FDC for the mission is normally located at or near the weapon position.

b. Assault fire is used for the destruction of caves, pillboxes, or other fixed fortifications with sufficient vertical dimensions.

c. See paragraph 242 for example mission.

217. Ammunition Used for Assault Fire

a. *Projectile.* Shell HE is used for assault fire.

b. *Fuzes.* Concrete-piercing (CP) fuzes are appropriate for destruction of fortifications. Fuze quick or fuze concrete-piercing, nondelay, is used for adjustment and to clear away rubble; fuze concrete-piercing, delay, may be used for fire for effect to effect penetration. Fuze quick or fuze concrete-piercing, nondelay, if concrete-piercing fuze is not available. Fuze M51 is used to cut through a parapet or earth covering, after which the appropriate fuze CP or fuze M51, delay, is used to effect destruction of the fortification. If excessive ricochets result from the use of concrete-piercing delay fuze, nondelay fuze should be used until enough cratering has been effected to prevent ricochet of the delay fuze.

218. Preparatory Operations

The observer and all personnel concerned with an assault fire mission should prepare detailed plans for the mission. Thorough planning, reconnaissance, and coordination must be completed before the weapon position is occupied. The observer must occupy an observation post as near the target as possible and on or near the gun-target line.

219. Initial Data

Normally, initial data are prepared in advance by use of the best means available

(usually survey) to locate the target with respect to the assault weapon position. Therefore, in most cases, a complete initial fire request from the observer is not necessary.

220. Adjustment

a. Adjustment is made by using a modified procedure in which the observer exercises complete control of fire throughout the mission. Corrections in meters are given by the observer for each successive round until the point of impact is on the desired portion of the target. An off-line burst is corrected to bring subsequent bursts to the line through normal adjustment procedure except that deviation corrections should be given to the nearest meter. The target is bracketed for range, and the bracket is split successively.

b. When the bursts are very near the target, the observer normally is able to estimate vertical error more accurately than he can estimate range error. Therefore, after bursts have been brought close to the target, the observer makes corrections for site rather than range. The point at which the observer begins adjusting site instead of range cannot be prescribed exactly; it depends on terrain, vertical dimensions of the target, and experience and ability of the observer. As an example, for a target such as a cave entrance on a steep forward slope, after an observer splits a 50-meter range bracket, normally he can adjust site more easily than range. Thereafter the smallest correction appropriate in direction or site is one-half meter.

c. The observer usually will be able to see each round in flight as it travels toward the target. He will make more accurate sensings by noting the position of the round at the instant before the burst than by judging from the burst itself. This will enable the observer to make the small corrections necessary to attain pinpoint accuracy.

221. Fire for Effect

When the point of impact is on the desired portion of the target, the observer does not announce FIRE FOR EFFECT. He continues

to send a correction to the FDC for each round fired. All rounds are fired singly or as requested by the observer to permit the desired correc-

tions or changes in ammunition to be made between rounds. The initiative to control and to end the mission remains with the observer.

Section IV. CONDUCT OF FIRE USING COMBINED OBSERVATION

222. General

a. Combined observation is that type of observation in which two or more observers at different location are employed to obtain sensings on the same target. For effective conduct of fire using combined observations, the angle of intersection of the OT lines should not be less than 150 mils.

b. Combined observation is used for observing the following types of missions:

- (1) High-burst registration.
- (2) Center-of-impact registration.
- (3) Fire to obtain surprise through use of FFE transfers.
- (4) Surveillance of planned fires.

c. Observation posts should be established during daylight so that instruments may be oriented and a line materialized on the ground for orientation after dark. The OT azimuth of targets discovered during daylight is recorded by all observers. Targets may be located at night by placing the illuminated crosshairs of an observing instrument on the flash of an enemy weapon. Vertical angle and azimuth are recorded if adjustment is not started at once. As an expedient, direction to a flash may be materialized on the ground by a piece of white tape or two stakes.

223. Equipment

a. To obtain optimum accuracy, each observer should be equipped with a BC scope or an aiming circle.

b. Initial azimuth to the target can be obtained by the use of a compass. Subsequent deviations from the OT line can be measured with field glasses. However, the use of such equipment in this manner for combined observation is inaccurate. This inaccuracy may preclude the use of this method of adjustment during darkness.

224. High-Burst Registration

a. *General.* At night, visual adjustment of fire on a ground registration point is impossible without illumination. In desert, jungle, or arctic operations, clearly defined registration points in the target area often are not available. To provide for registrations under these conditions, special procedures have been developed. One such procedure is a high-burst registration using time fuze. (For FDC procedures see sec. III, ch. 19.)

b. *Orientation of Observer.* In a high-burst registration, two observers (01 and 02) are usually employed. The location of each observer and the desired point of burst are known at the fire direction center. The fire direction center will determine and furnish to each observer the azimuth and vertical angle to the expected point of burst. A typical message to the observers from FDC follows:

OBSERVE HIGH BURST. 01 AZIMUTH 1164, VERTICAL ANGLE PLUS 12, MEASURE THE VERTICAL ANGLE. 02 AZIMUTH 718, VERTICAL ANGLE MINUS 3. REPORT WHEN READY TO OBSERVE.

c. *Conduct of Registration.* Observers 01 and 02 orient their instruments on the azimuths and vertical angles given and report when ready to observe. (As soon as practicable after orientation of his instrument, the observer will set out on a known azimuth a stake which can be equipped with a light for night orientation.) The S3 directs the firing of one orienting round. The observer will orient the center of the reticle of his instrument on the point of burst. After the orienting round, the observer will not change the orientation of his instrument. The observed deviation on the reticle is combined with the reading set on the azimuth and micrometer scales to derive the measured azimuth. The same general procedure is used to measure the vertical angle. Both observers re-

port azimuth readings, but only the designated observer will report the vertical angle (e.g., based on the message to the observers in *b* above only observer 01 would report vertical angles).

225. Center-of-Impact Registration

Center-of-impact registration is conducted the same as the high-burst registration (para. 224), except that an impact fuze is employed instead of time fuze.

226. Combined Observation for Missions Other Than High-Burst or Center-of-Impact Registration

a. General. At long ranges (more than 4,000 meters), the use of combined observation may result in conservation of ammunition. Combined observation is especially important for heavy artillery, since observing ranges are normally so great that normal procedure is very difficult and sometimes impossible. (For FDC procedures see sec. VII, ch. 25.)

b. Observation Posts Plotted. If the OP's are plotted on the FDC charts the following procedures apply:

(1) Target location and orientation of OP's.

- (a) When accurate target location is furnished by higher headquarters, the OP's are oriented by FDC using procedures described in paragraph 224b.
- (b) When one observer locates the target accurately, FDC may orient the other observer.
- (c) When one observer locates a target, he may orient the other observer on the location of the target. Both observers may then report azimuths to the target, and the FDC can locate the target by intersection.

- (2) *Procedure during adjustment.* When both observers report ready to observe, firing is begun. The observers report the azimuths and vertical angles to each burst. If so directed, the observers report deviations (number of mils right or left of OT line) rather than azimuths.

227. Target Area Base

A target area (short) base (fig. 65) may be established to locate targets rapidly. It is composed of two observation posts from which points in the target area can be located by a combination of triangulation and polar plotting. Distances are computed, but the targets are placed on the firing chart by polar plotting. The base should be long enough to give an angle of intersection at the target of at least 150 mils. The base should be as nearly perpendicular to the direction to the target area as possible. 01, the control OP, should be accurately located and plotted on the firing chart; 02, the secondary OP, need not be plotted, but the distance and direction from 01 to 02 must be accurately measured.

a. The instruments at the two OP's are oriented by sighting on one another with scales set at 0. Instrument readings (horizontal clockwise angles from the left end of the base, or the base extended, to the target) are measured at each observation post.

b. The apex angle (the angle at the target formed by the intersection of the lines of site from the two OP's) is determined by subtracting the instrument reading of the right OP from the instrument reading of the OP on the left. (An exterior angle of a triangle is equal to the sum of the opposite interior angles.)

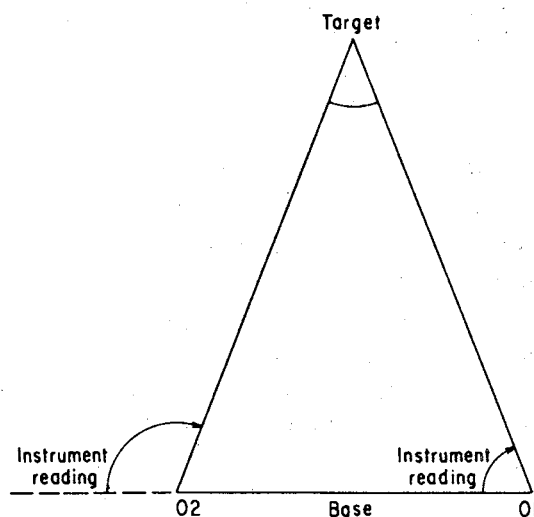


Figure 65. Target area (short) base.

c. The distance from 01 to the target is solved by using the law of sines, as follows:

$$\frac{\text{Distance 01 to target}}{\sin \text{instrument reading 02}} = \frac{\text{Base}}{\sin \text{apex angle}}$$

In applying the law of sines, an exterior angle may be substituted for the adjacent interior angle, since the sines of supplementary angles are equal. The use of an exterior angle is required in the above formula when 02 is on the left.

d. The military slide rule is arranged to provide a rapid and simple solution to the short base problem. The steps in the solution are as follows:

- (1) Place the hairline of the indicator over the value of the 02 instrument reading on the scale marked "opposite angle."
- (2) Move the slide until the value of the apex angle of the scale marked "apex angle" is under the hairline.
- (3) Move the indicator until the hairline is over the length of the base on the C (base) scale.
- (4) Read the distance from 01 to the target on the D (range) scale.

e. The target location is reported to FDC by polar coordinates from 01 as AZIMUTH (so much), UP (DOWN) (so much), DISTANCE (so much).

Section V. ADJUSTMENT OF HIGH-ANGLE FIRE AND AUXILIARY ADJUSTING POINT

228. General

a. Fire delivered at elevations greater than the elevation for maximum range is called high-angle fire. High-angle fire is often required when the weapons fire out of deep defilade, from within cities, or over high terrain features near friendly troops. High-angle fire may also be required when targets are located directly behind hill crests, in jungles, or in deep gullies or ravines and cannot be reached by low-angle fire.

b. Most artillery weapons are capable of firing high-angle fire. Generally, those cannon which have a maximum elevation substantially in excess of 800 mils have the capability of firing high-angle fire.

229. Determining Requirements for High-Angle Fire

Usually an observer can determine whether high-angle fire is required for any given target; if he cannot determine this, the observer should notify the FDC that high-angle fire may be necessary. In any case, the S3 decides whether high-angle fire is to be used and will notify the observer of its use.

230. Initial Fire Request

a. When high-angle fire is desired, the observer so indicates in his initial fire request.

b. An accurate initial location of the target is desirable because large shifts during adjustment may necessitate a change of charge, since there is little or no overlap in ranges reached by various charges.

c. The excessive height of burst probable error associated with a long time of flight makes time fire undesirable. Because of the steep angle of fall, ricochet fire is seldom possible.

d. Quick and VT fuzed projectiles give excellent effect from side spray because of the steep angle of fall. VT fuzes produce a lower height of burst than normally obtained with low-angle fire.

231. Adjustment

a. The observer procedure for the adjustment of high-angle fire is the same as that for low-angle fire.

b. The observer must realize that small corrections during adjustment may be unnecessary and time-consuming owing to the increased dispersion experienced during high-angle fire.

c. Since the time of flight is long, in both adjustment and fire for effect, the FDC will give ON THE WAY, when the round(s) is fired, and SPLASH, 5 seconds before the burst(s) occurs. Air observers are given ON THE WAY, TIME OF FLIGHT (so much), and SPLASH.

232. Auxiliary Adjusting Point

In order to achieve surprise, the observer may decide not to adjust on the target but to adjust on a nearby point. This nearby point, the auxiliary adjusting point, must be far enough away from the target that the real purpose of

the adjustment is obscured. At the same time, the auxiliary adjusting point must be so selected that an accurate shift to the target may be determined. When the adjustment on the auxiliary adjusting points is complete, the shift to the target is made.

Section VI. CONDUCT OF FIRE WHEN OBSERVER IS NOT ORIENTED

233. General

In a rapidly moving situation, an observer might become confused and disoriented. An observer in a moving tank has a problem in orientation because his OT azimuth is constantly changing. To bring fire upon a target when the azimuth is changing rapidly or is unknown requires that both the observer and FDC exercise judgment and initiative.

234. Target Location

If possible, the target location is determined by using the procedures prescribed in chapter 8. If target location by normal means is not possible, the observer must request that a round

be fired at a point where he can identify it and use that round as his known point (para. 138).

235. Gun-Target Line Method of Adjustment

When the observer cannot determine the OT azimuth or when the OT azimuth is changing frequently, as is the case with observers with tank units, the observer may decide to adjust with respect to the gun-target line. To determine the direction of the GT lines it may be necessary to request ranging rounds (weapon fires two rounds at the same deflection but 400 meters apart in range). When the observer is adjusting with respect to the GT line, the S3 should select a unit to fire whose location will result in the smallest angle T.

CHAPTER 14

ILLUSTRATIVE EXAMPLES

236. General

The examples of missions contained in this chapter are typical of those that an observer may be called on to fire. In the examples in paragraphs 237 through 242, the symbols indicate the following: +, a sensing of "over"; —, a sensing of "short"; and ?, a sensing of "doubtful."

237. Precision Registration Mission

Target: surveyed registration point; mission: registration; material: 105-mm howitzer; ammunition: shell HE with superquick fuze.

*Messages, corrections,
and commands*

Observer to FDC (fire request):

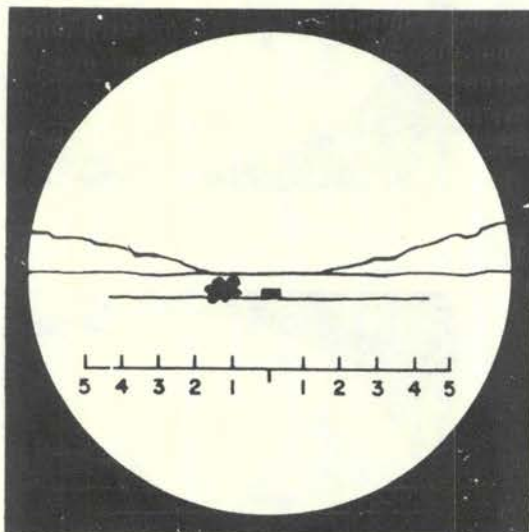
FIRE MISSION, REGISTRATION POINT 1, AZIMUTH 4710, REGISTRATION, WILL ADJUST:

FDC will transmit to the observer those elements of interest to him.

FDC to observer:
ON THE WAY.

Results

*Sensings
Rg Dev*



? 15L

Remarks: Estimated OT distance = 3,000 meters. With field glasses, observer measured deviation (dev) of burst 15 mils left of OT line. Observed deviation = 45 meters (15 x 3.0). No range sensing is obtained. Observer determines shift of right 40 (45) to bring next burst to the OT line.

*Messages, corrections,
and commands*

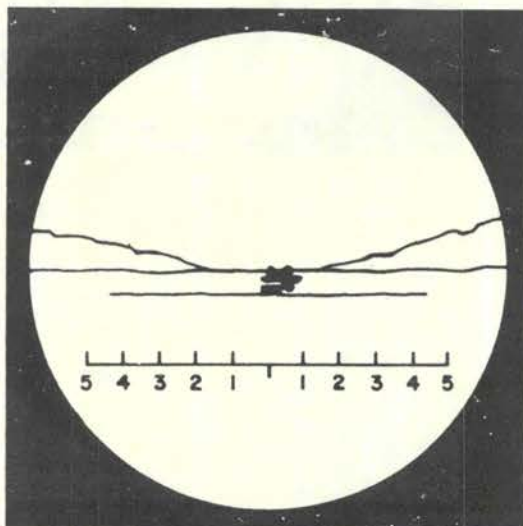
Observer to FDC:

RIGHT 40, REPEAT RANGE.

FDC to observer:
ON THE WAY.

Results

*Sensings
Rg Dev*



+ Line

Remarks: The burst has been brought to the OT line. From this sensing of OVER, the observer decides to make a range change of 200 meters.

*Messages, corrections,
and commands*

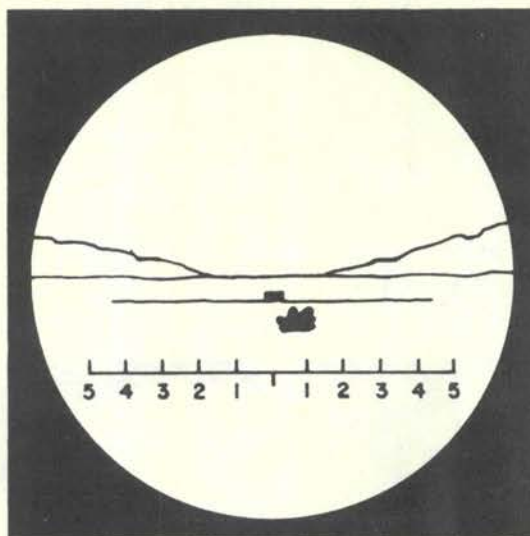
Observer to FDC:

DROP 200.

FDC to observer:

ON THE WAY.

Results



Sensings
Rg Dev

— Line

*Messages, corrections,
and commands*

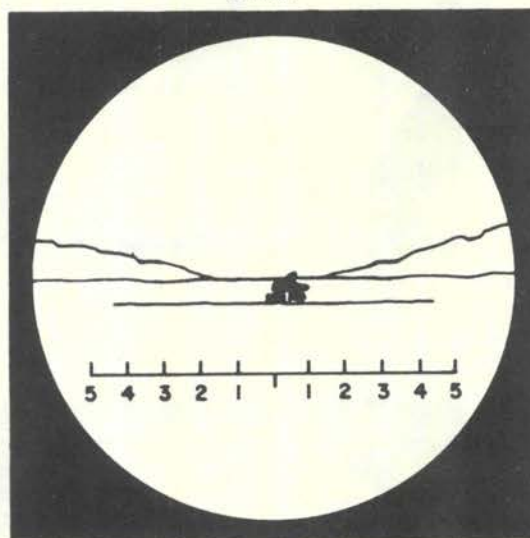
Observer to FDC:

ADD 100.

FDC to observer:

ON THE WAY.

Results



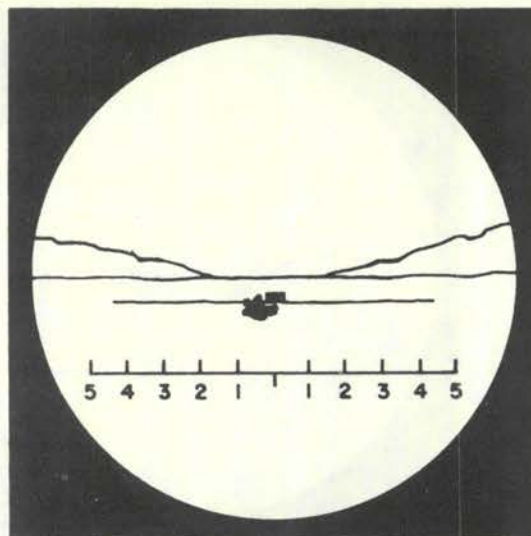
Sensings
Rg Dev

+ Line

Remarks: A 100-meter bracket now has been obtained along the OT line. With the next round, the observer will request a change of 50 meters which will be the first round in fire for effect (trial range).

*Messages, corrections,
and commands*

Observer to FDC:
DROP 50, FIRE FOR
EFFECT.
FDC to observer:
ON THE WAY.
Observer to FDC:
SHORT, LINE.

Results

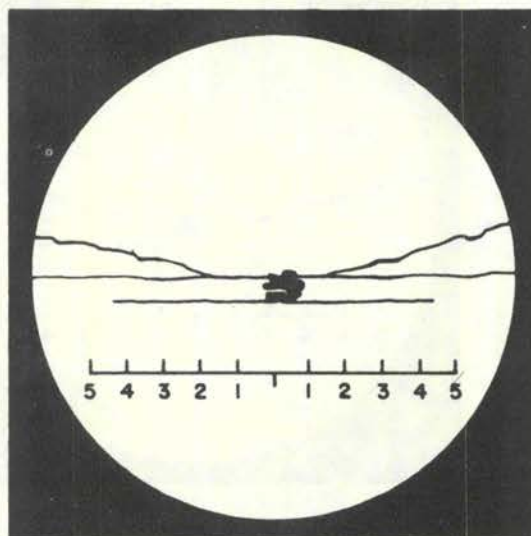
Sensings
Rg Dev

— Line

Remarks: No further corrections by the observer are given. The S3 assumes control and continues the mission until he has sufficient sensings from which to compute an adjusted elevation. The observer reports only his sensings.

*Messages, corrections,
and commands*

FDC to observer:
ON THE WAY.
Observer to FDC:
OVER, LINE.

Results

Sensings
Rg Dev

+ Line

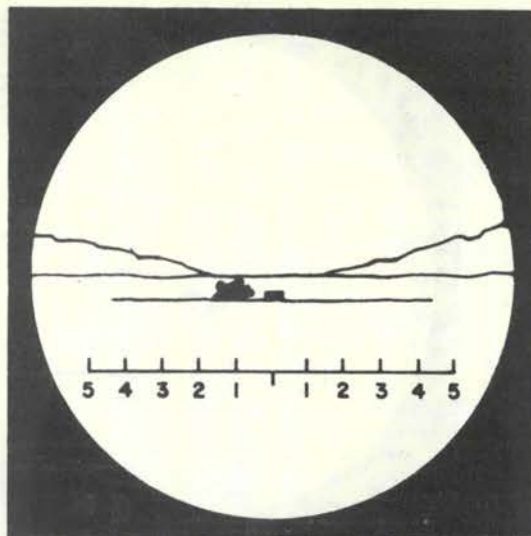
Messages, corrections,
and commands

FDC to observer:
ON THE WAY.
Observer to FDC:
DOUBTFUL, LEFT.

Results

Sensings
Rg Dev

? Left



Remarks: This round appears off the OT line. The observer senses the round as DOUBTFUL, LEFT.

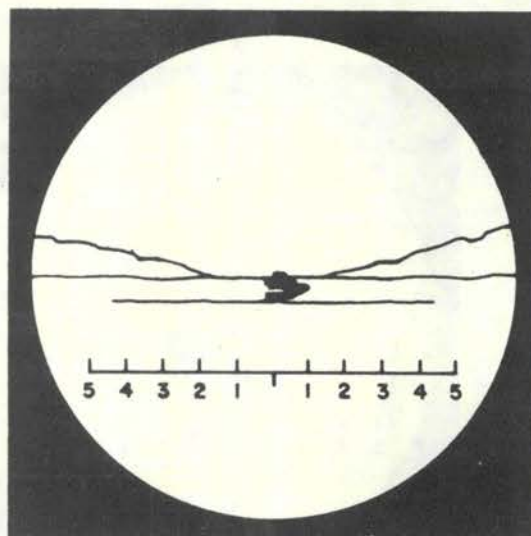
Messages, corrections,
and commands

FDC to observer:
ON THE WAY.
Observer to FDC:
OVER, LINE.

Results

Sensings
Rg Dev

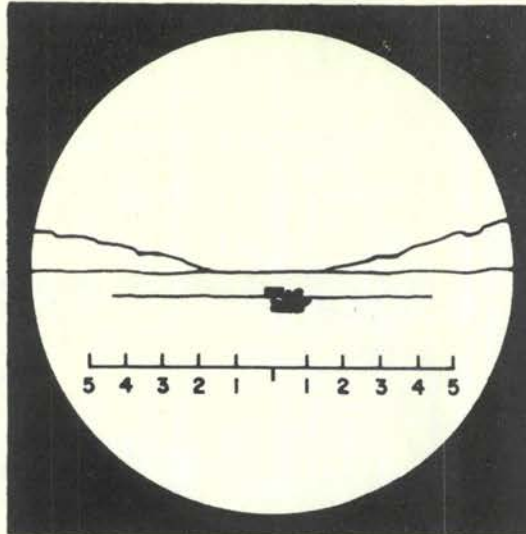
+ Line



*Messages, corrections,
and commands*

FDC to observer:
ON THE WAY.
Observer to FDC:
SHORT, LINE.

Results



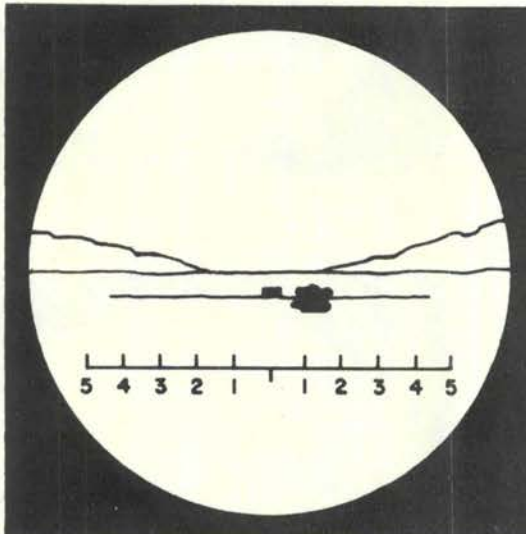
Sensings
Rg Dev

— Line

*Messages, corrections,
and commands*

FDC to observer:
ON THE WAY.
Observer to FDC:
SHORT, RIGHT.

Results



Sensings
Rg Dev

— Right

Remarks: The S3 has now obtained six usable sensings and, therefore, notifies the observer that the mission has been accomplished.

*Messages, corrections,
and commands*

FDC to observer:

END OF MISSION.

238. Time Registration Mission

Target: registration point; mission: time registration (it is assumed that the observer has just completed a precision registration on the registration point, using time-fuzed shell set on quick); materiel: 105-mm howitzer; ammunition: shell HE, fuze M500.

*Messages, corrections,
and commands*

FDC to observer:

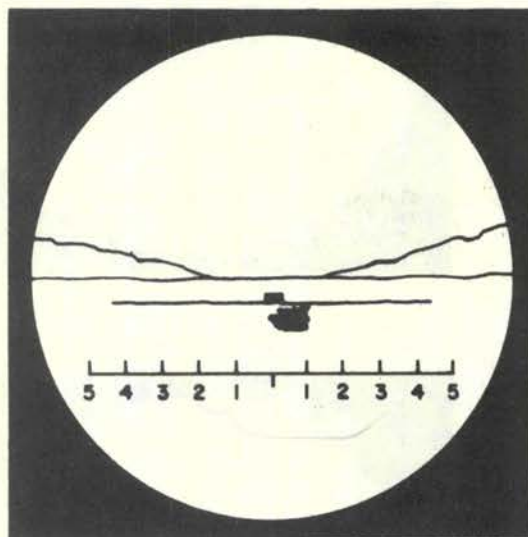
OBSERVE TIME REGIS-
TRATION, ON THE
WAY.

Observer to FDC:

GRAZE.

Results

Sensings



G

*Messages, corrections,
and commands*

FDC to observer:

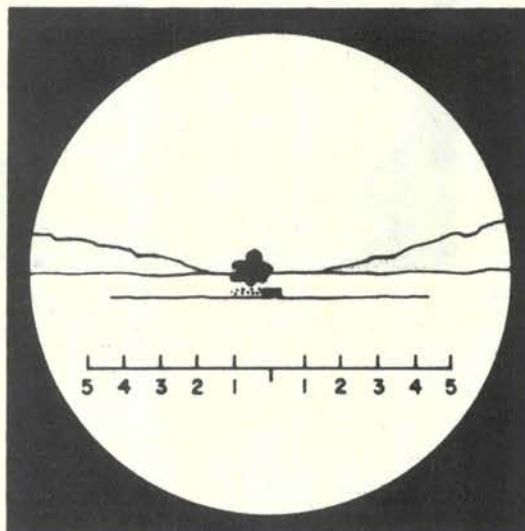
ON THE WAY.

Observer to FDC:

AIR.

Results

Sensing



A

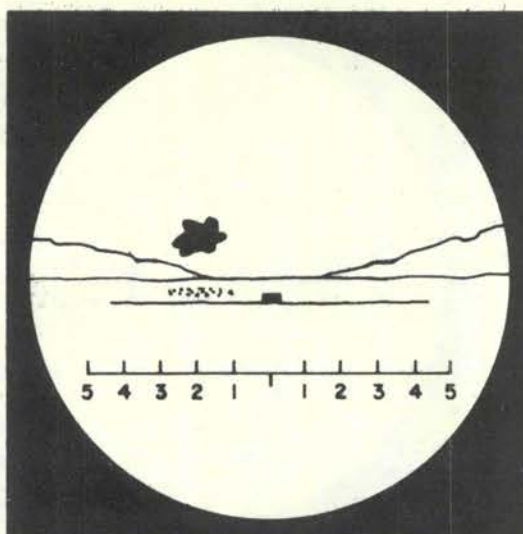
*Messages, corrections,
and commands*

FDC to observer:
OBSERVE
3 ROUNDS,
ON THE WAY.

Results

Sensing

A

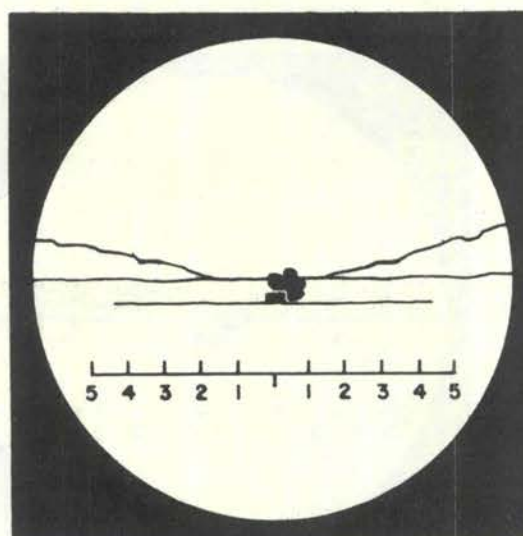


*Messages, corrections,
and commands*

Results

Sensing

G



FM 6-40

*Messages, corrections,
and commands*

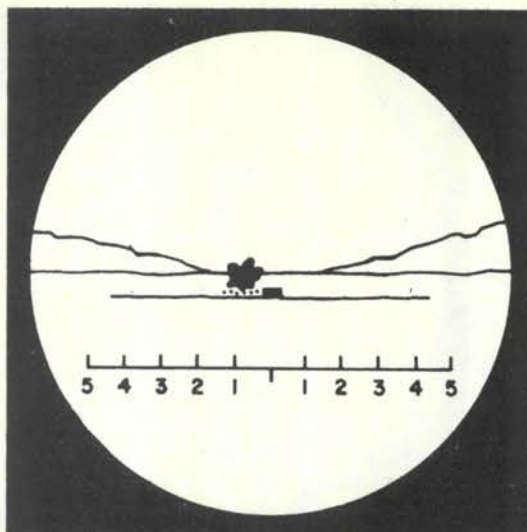
Observer to FDC:

AIR, GRAZE, AIR.

Results

Sensing

A



Remarks: Two more rounds will be fired at the graze end of time bracket to obtain six time sensings.

*Messages, corrections,
and commands*

FDC to observer:

OBSERVE

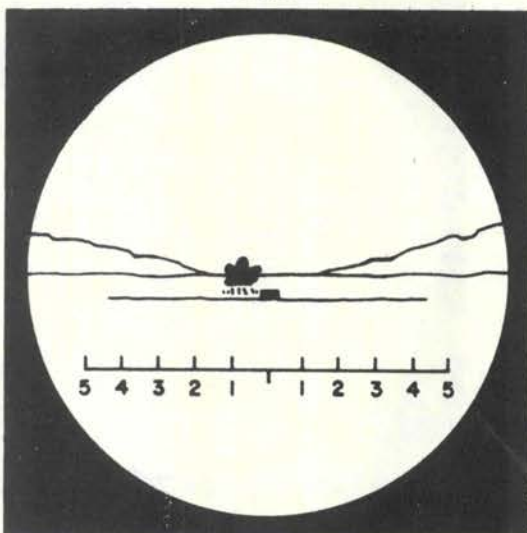
2 ROUNDS,

ON THE WAY.

Results

Sensing

A

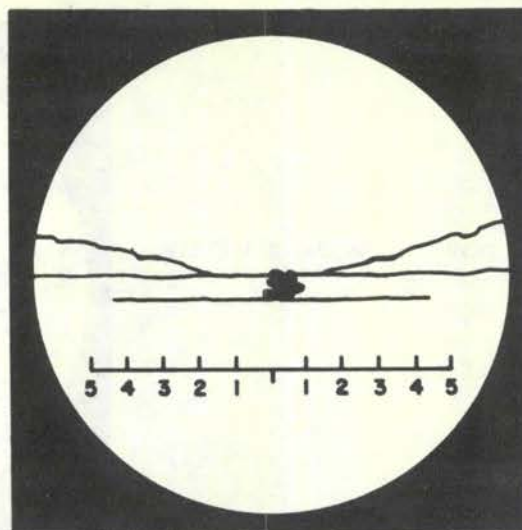


Messages, corrections, and commands

Results

Sensing

Observer to FDC:
AIR, GRAZE.



G

Messages, corrections, and commands

FDC to observer:
END OF MISSION.

239. Area Fire Mission

Target: machineguns; mission: neutralization; materiel: 105-mm howitzer; ammunition: shell HE (both M51 and M500 fuzes in battery). Shift from registration point.

Messages, corrections, and commands

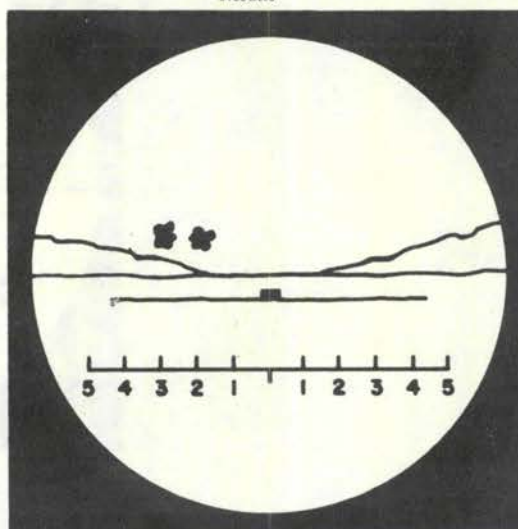
Results

Sensings
HB Rg Dev

Observer to FDC (fire request):

FIRE MISSION, FROM REGISTRATION
POINT 1, AZIMUTH 1880, LEFT 660,
DROP 1000, MACHINEGUNS, FUZE
TIME, WILL ADJUST. FDC will transmit
to the observer those elements of the fire order
of interest to him.

FDC to observer:
ON THE WAY.



A ? 25L

Remarks: Estimated OT distance=2,000 meters. With field glasses, observer measures deviation of burst center 25 mils left of the OT line. Observed deviation=50 meters (25×2.0). No range sensing is obtained. Observed height of burst (HB)=30 meters (15×2.0).

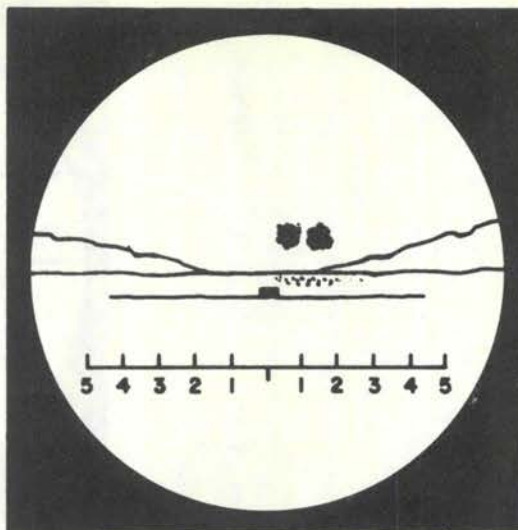
Messages, corrections, and commands

Results

Sensings
HB Rg Dev

Observer to FDC:
RIGHT 50, DOWN 10, REPEAT RANGE.

FDC to observer:
ON THE WAY.



A + 10R

Remarks: Deviations of 10 mils is small. The observer elects to ignore it inasmuch as he is able to obtain a range sensing. If a range sensing were not obtainable, this deviation would be corrected.

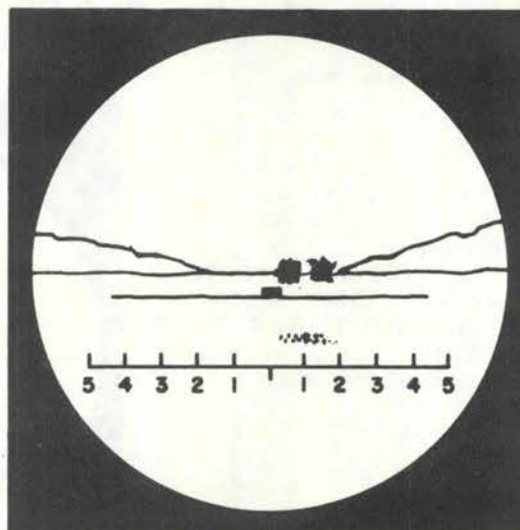
Messages, corrections, and commands

Results

Sensings
HB Rg Dev

Observer to FDC:
DROP 400.

FDC to observer:
ON THE WAY.



A - 10R

*Messages, corrections,
and commands*

Observer to FDC:

ADD 200.

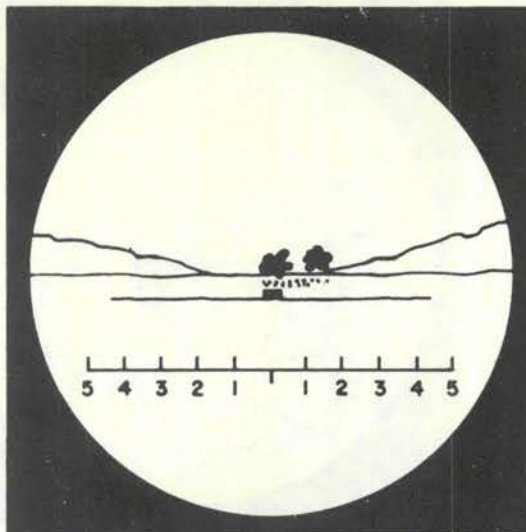
FDC to observer:

ON THE WAY.

Results

HB	Sensings Rg	Dev
----	----------------	-----

A	+	8R
---	---	----



Remarks: The deviation of 8 to 10 mils right still exists. The observer, therefore, considers it in his next correction.

*Messages, corrections,
and commands*

Observer to FDC:

LEFT 20,

DROP 100.

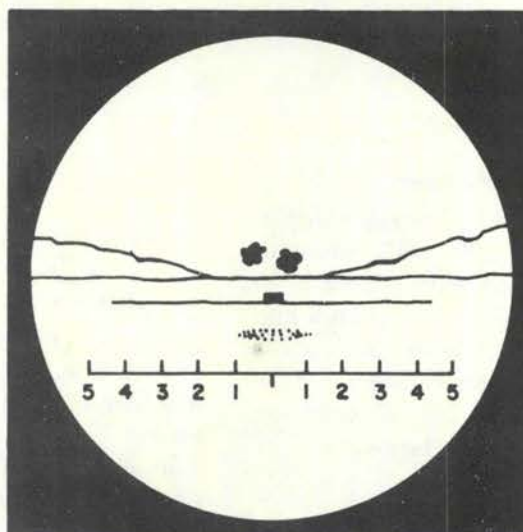
FDC to observer:

ON THE WAY.

Results

HB	Sensings Rg	Dev
----	----------------	-----

A	-	Line
---	---	------



(Desired height of burst.)

Messages, corrections,
and commands

Observer to FDC:

ADD 50,

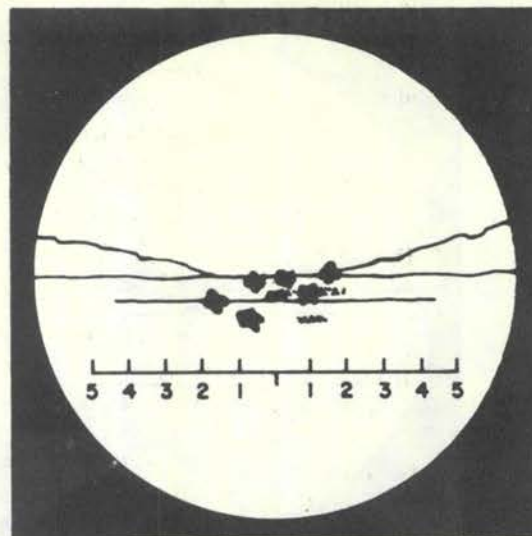
FIRE FOR EFFECT.

FDC to observer:

FIRING FOR EFFECT.

Results

HB Sensings
Rg Dev



Mixed Range
air cor-
rect Line

Remarks: First volley in effect sensed *mixed*, *range correct*, *line*. Remainder of fire is observed, and, if necessary, corrections are sent to the fire direction center.

Messages, corrections,
and commands

Observer to FDC:

END OF MISSION,
MACHINEGUNS
SILENCED.

240. Illuminating Shell Mission

a. Observer hears a number of heavy vehicles at an azimuth estimated at 5,800 mils. He cannot detect any lights and the entire area is in complete darkness. Judging from sound and map study, the observer estimates the source of the noises to be grid reference 725365. This is about 2,000 meters from his observation post. He sends the following fire request:

RANGER 9, THIS IS RANGER 31,
FIRE MISSION,
COORDINATES 725365,
AZIMUTH 5800,
VEHICLE NOISES—SUSPECTED TANKS,
ONE GUN,
ILLUMINATING,
WILL ADJUST.

b. The first illuminating round bursts about 100 mils left of the suspected area and 150 meters too high. Observer transmits—

RIGHT 200,
DOWN 150,
REPEAT RANGE.

c. The second round bursts short near the OT line but too low—the round burns 5 seconds on the ground. Observer requests—

UP 50 ($T \times 10 = 50$),
ADD 400.

d. The third round bursts at a good height over the suspected area, but haze, along with distance of area from observer, makes visibility poor with only one round of illuminating shell. The observer feels that two rounds will be adequate but desires a lateral spread along a section of road which he is observing to extend the visible area and reduce shadows. Observer requests—

TWO GUNS,
DEFLECTION SPREAD,
REPEAT RANGE.

e. Two rounds burst in a spread over the suspected area, and the observer notices two tanks and a number of infantry moving out to the right at the extreme right edge of the illuminated area. He determines a shift from the

center of illumination and transmits the following:

RIGHT 400,
REPEAT RANGE,
CONTINUOUS ILLUMINATION (and
immediately after),
FROM ILLUMINATION,
AZIMUTH 6100,
SHELL HE,
REPEAT RANGE,
TWO TANKS AND PLATOON OF INFANTRY,
FUZE QUICK AND VT IN EFFECT,
AT MY COMMAND,
WILL ADJUST.

f. Continuous illumination is begun over the desired point, disclosing two additional tanks and more infantry. FDC reports READY. As soon as the next illuminating shell bursts, observer orders FIRE. He acknowledges FDC's report of ON THE WAY and gives a new description of the target at this time, as FOUR TANKS AND PLATOON OF INFANTRY.

g. Observer adjusts HE during continuous illumination and fire for effect is delivered. The fire for effect apparently causes several casualties among the infantry troops. Observer's order to fire for effect was DROP 50, FIRE FOR EFFECT. He retains control of the time of firing to observe the effect.

h. Tanks and remaining infantry are moving out to the northwest away from the observer. It is necessary to shift illumination, and observer desires to repeat fire for effect against the target. He orders—

ILLUMINATING,
ADD 400,
HE,
LEFT 50,
REPEAT RANGE, REPEAT FIRE FOR EFFECT.

i. Tanks and infantry have moved out of observation capabilities of observer so he orders—

END OF MISSION,
TANKS AND INFANTRY DISPERSED TO
NORTHWEST,
REQUEST REPLOTT.

241. Searchlight Mission

a. Observer hears movement and suspects an attempt is being made to repair a disabled tank which is blocking a road in his sector. Search-

lights are available, and a study of the terrain indicated that it is possible to illuminate the tank directly. He sends the following mission:

THIS IS RANGER 31,
ILLUMINATION MISSION,
COORDINATES 67184437,
AZIMUTH 780,
SUSPECTED ACTIVITY AROUND DISABLED
TANK,
TWO LIGHTS,
WILL ADJUST.

b. Left beam appears below the target, and right beam is two beam widths to the left. He orders NUMBER 1, RIGHT TWO BEAMS: NUMBER 2, UP ONE-HALF BEAM.

c. Both beams having been centered on the target, the observer orders HOLD. This command HOLD causes the lights to be held on the target and allows the observer to call for a destruction mission on the tank. After the tank is destroyed, the observer will terminate the mission as indicated below:

END OF MISSION, STALLED TANK
DESTROYED.

d. If, in the course of the HE mission, the observer decides it is better to cut off the lights but wants to hold the position of the lights, he orders HOLD, CUT. To restore light to the target he next orders FLICK.

e. Using these commands, together with artillery fire AT MY COMMAND, the observer is able to light the target for surveillance or adjustment and hold to a minimum the exposure of friendly light positions.

242. Assault Fire Mission

Target: cave in hard rock of hillside; Mission; to seal cave entrance; materiel: 8-inch howitzer; gun-target range: 1,500 meters; observer-target distance: 1,000 meters. The mission has been prearranged in detail, and a complete initial fire request is unnecessary. The observer reports when he is ready to observe and the FDC personnel, having carefully prepared all data in advance, sends commands to the howitzer to fire the first round. Fired at such short range with precise initial data, the first round should be close to the target.

<i>Remarks</i>	<i>Observer corrections</i>
First round bursts 10 mils right of OT line, doubtful for range.	LEFT 10, REPEAT RANGE.
Second round bursts between observer and target.	ADD 50.
Third round bursts beyond target.	DROP 25.
Fourth round bursts just above upper right corner of cave entrance. (Changes in site instead of range are now appropriate.)	LEFT 1, DOWN 1, REPEAT RANGE.

<i>Remarks</i>	<i>Observer corrections</i>
Fifth round bursts at left edge just below cave entrance.	RIGHT ½, UP ½, REPEAT RANGE.
Sixth round is in cave entrance. Fuze CP delay is now appropriate to penetrate hard rock.	FUZE CONCRETE-PIERCING DELAY, REPEAT RANGE.
Seventh round also bursts in cave entrance. Cave is now almost completely sealed.	REPEAT RANGE.
Eighth round strikes top of cave entrance, completely sealing it with rubble.	END OF MISSION, CAVE ENTRANCE SEALED.

PART FOUR

FIRE DIRECTION

CHAPTER 15

FIRE DIRECTION, GENERAL

Section I. INTRODUCTION

243. Definitions

a. Fire Direction. Fire direction is the tactical employment of firepower, the exercise of tactical command of one or more units in the selection of targets, the concentration or distribution of fire, and the allocation of ammunition for each mission. Fire direction also includes the methods and techniques used in fire direction centers to convert fire missions into appropriate fire commands.

b. Tactical Fire Direction. Tactical fire direction is the exercise of tactical command of one or more units in the selection of targets, designation of units to fire, and the allocation of ammunition for each mission.

c. Technical Fire Direction. Technical fire direction is the conversion of fire missions to appropriate firing data and fire commands.

d. Fire Direction Center. The fire direction center is the element of the artillery headquarters that consists of operations, intelligence, and communication personnel and equipment by means of which the commander directs artillery fire.

244. Scope

This manual is concerned primarily with technical fire direction for field artillery cannon battalions and batteries. For tactical fire direction at battalion level, see FM 6-21. See FM 6-20 for fire direction above battalion.

245. Principles of Fire Direction

The methods employed in fire direction must insure—

a. Continuous, accurate, and timely fire support under all conditions of weather, visibility, and terrain.

b. Flexibility sufficient to engage all types of targets over a wide area.

c. Prompt massing of fires of all available units in any area within range.

d. Prompt distribution of fires simultaneously on numerous targets within range.

246. Command

a. Artillery headquarters control the fires of subordinate units. The headquarters may allocate reinforcing artillery fires in order to further the plan of the force commander. Division, group, corps, and army artillery headquarters are concerned primarily with tactical fire direction.

b. Fire direction as exercised by a cannon artillery battalion consists of tactical fire direction as well as technical fire direction.

c. When a battery is operating independently, fire direction is exercised by the battery commander through his executive officer and the fire direction personnel at the **battery fire direction center**.

Section II. FIRE DIRECTION CENTER

247. Role of the Fire Direction Center

The fire direction center (FDC) is that element of the gunnery team which receives the observer's fire request (or fire mission from higher headquarters), determines firing data and fire commands

based on that request, and announces the fire commands to the firing battery. The fire direction center also determines and applies corrections to standard firing table values in order to achieve the accuracy in firing that must be characteristic of field artillery.

248. Principles of Operation

a. Production of Firing Data. Firing data are normally produced in the battalion FDC. In the following circumstances, firing data may be produced in the battery:

- (1) When the battery is operating independently.
- (2) When more than two missions are being processed simultaneously and the S3 directs the battery to produce its own firing data.

b. Processing Fire Missions. Accuracy, flexibility, and speed in the execution of fire missions depend on—

- (1) Accurately and rapidly preparing firing data from the firing chart and transmitting commands to the firing batteries.
- (2) Accurately and rapidly verifying firing data.
- (3) Efficient division of duties.
- (4) Adherence to a standard technique and procedure.
- (5) Efficient use of FDC plotting and data determining devices.
- (6) The functioning of personnel as a team in a specified sequence.
- (7) Efficient communications, including use of a battalion fire direction center switchboard.

Section III. FIRING CHARTS**250. General**

The firing chart is a photomap, grid sheet, or a sheet of plain paper on which is shown the relative locations of batteries, registration points, targets, and other details needed in preparing firing data.

251. Map

A map is a graphic representation, drawn to

249. Fire Direction Center Personnel (Battalion)

The personnel that operate the fire direction center are listed in *a* through *g* below. Detailed descriptions of their duties are given in chapter 23.

a. Battalion S3. The battalion S3 is the gunnery officer of the battalion and is responsible for the functioning of the fire direction center. The assistant S3 must be capable of assuming the duties of the S3 whenever necessary.

b. Chief Fire Direction Computer. The chief fire direction computer is the senior enlisted member of the FDC and assists the S3 in the supervision of the fire direction center.

c. Horizontal Control Operator. The horizontal control operator (HCO) operates the horizontal control chart, normally a grid sheet, from which range and direction are determined.

d. Vertical Control Operator. The vertical control operator (VCO) operates the vertical control chart, normally a **grid sheet supplemented by a 1:50,000 map**, and determines site.

e. Computer. The computer (one per firing battery) converts chart data to firing data and announces fire commands to the firing battery.

f. Switchboard Operator. The switchboard operator installs and operates the FDC switchboard.

g. Radiotelephone Operator(s). The radio telephone operator receives, records, and reads back fire requests.

scale, of a portion of the earth's surface. **Maps (normally 1:50,000) are used to supplement firing charts.** A map is only as accurate as the ground survey from which it is made. Maps based on accurate ground survey require the least amount of addi-

tional survey for field artillery use. These maps provide direction and horizontal and vertical control and can be used as the basis for field artillery survey. If the map is not based on accurate and adequate ground control, it should be used only to obtain approximate locations and vertical control to supplement a grid sheet firing chart.

252. Photomap

a. A photomap is a reproduction of an aerial photograph or a mosaic on which are added grid lines, marginal information, and place names. Photomaps must not be considered exact until their accuracy has been verified. Errors caused by tilt, distortion due to relief, and errors due to poor assembly may be present in mosaics. If points cannot be located on the photomap by inspection, the scale must be determined before points can be located on the photomap by survey. Normally, vertical control can be established only by estimation. Some photomaps have spot elevations, but interpolation is difficult and inaccurate.

b. Even though the photomap may be used initially, survey is started at once. This survey provides a check on the accuracy of the photomap. If the photomap proves to be inaccurate, a grid sheet firing chart based on survey is constructed.

253. Grid Sheet

A grid sheet is a plain sheet of paper on which are printed equally spaced horizontal and vertical lines called grid lines. Since the grid sheet bears no relation to the ground and basic information must come from other sources, any scale desired may be used. However, grid sheets used by the field artillery are printed with the distance between grid lines

representing 1,000 meters at a scale of 1:25,000. The location of all points placed on the grid sheet must be determined either by survey or firing. Horizontal and vertical control charts are usually grid sheets.

254. Purpose of Firing Chart

The firing chart is used to determine the range, direction, and vertical interval from the gun(s) to the target. The effectiveness of artillery fires depends to a large degree on the accuracy and completeness of the firing chart.

255. Types of Firing Charts

There are two types of firing charts used on an FDC—the surveyed firing chart and the observed firing chart.

a. The surveyed firing chart is a chart on which the locations of all key points (battery positions, registration points, OP's) are based on survey (FM 6-2). All plotted points are in correct relation to one another and are tied together by actual map coordinates. When determination of actual map coordinates has not been completed, assumed coordinates may be used initially to tie together the points to be plotted. The procedures pertaining to construction of a surveyed firing chart and determination of data therefrom are covered in chapter 16.

b. The observed firing chart is a chart on which all chart locations must be established by firing. Relative locations of the batteries and targets can only be established by the adjustment of fire, hence the name "observed firing chart." Procedures pertaining to determination of data stated in chapter 16 apply to an observed firing chart. Details pertaining to construction of an observed firing chart are contained in chapter 26.

CHAPTER 16

CHART DATA

Section I. PLOTTING

256. General

Every effort must be made to insure the accuracy of data shown on the firing chart. All firing charts in the battalion should be identical to insure that any chart can be used to mass the fires of the battalion.

257. Plotting Equipment

The construction and use of a firing chart requires the use of special equipment. The accuracy obtained with this special equipment depends as much on plotting habits and care of equipment as on the accuracy of the equipment.

a. *The 6H Pencil* (1, fig. 66). Any line drawn on the firing chart from which measurements will be made must be drawn with a 6H (hard lead) pencil, sharpened to a wedge point. This procedure is required if the necessary accuracy is to be achieved.

b. *The 4H Pencil* (2, fig. 66). The 4H pencil is used for lettering and to accentuate tick marks. It should be sharpened to a conical point.

c. *Map Pins* (3, fig. 66). Map pins commonly referred to as plotting pins, are used to mark battery, radar, and OP positions and to plot all points on the firing chart.

d. *Plotting Scale* (1, fig. 67). The plotting scale is used for measuring distances and for plotting and determining coordinates for critical points, such as batteries, radar, OP's, and registration points, which must be located accurately. The scale should always be used in plotting coordinates determined by survey computations. The scale is graduated in meters, yards, and inches. The meter and yard graduations are at scales of 1:25,000, 1:50,000 and 1:62,500. The plotting scale should never be used as a straight-edge for drawing lines.

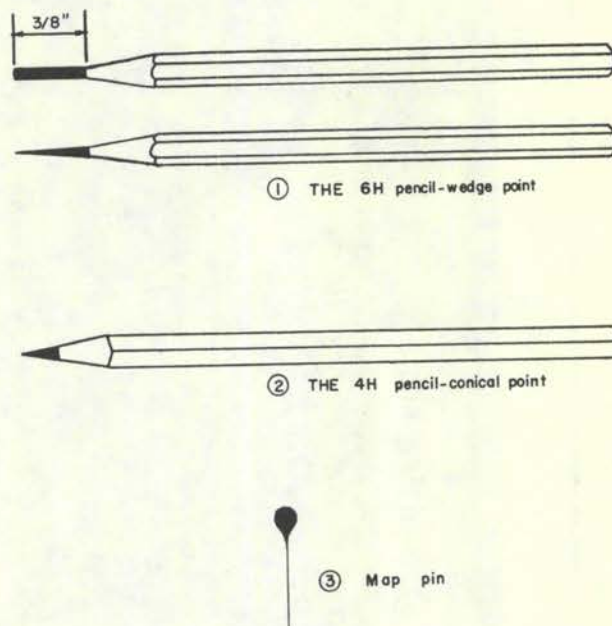


Figure 66. Pencils, pins, and needles.

e. *Coordinate Scale (Aluminum)* (2, fig. 67). The aluminum coordinate scale is a square-shaped scale used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at scales of 1:25,000 and 1:50,000. The scale has a projecting knob for ease in handling.

f. *Coordinate Scale (Plastic)* (3, fig. 67). The plastic coordinate scale is a right-angled scale used for plotting and determining coordinates of targets other than registration points and coordinates determined by survey computations. This scale is graduated in meters and yards at scales of 1:25,000 and 1:50,000.

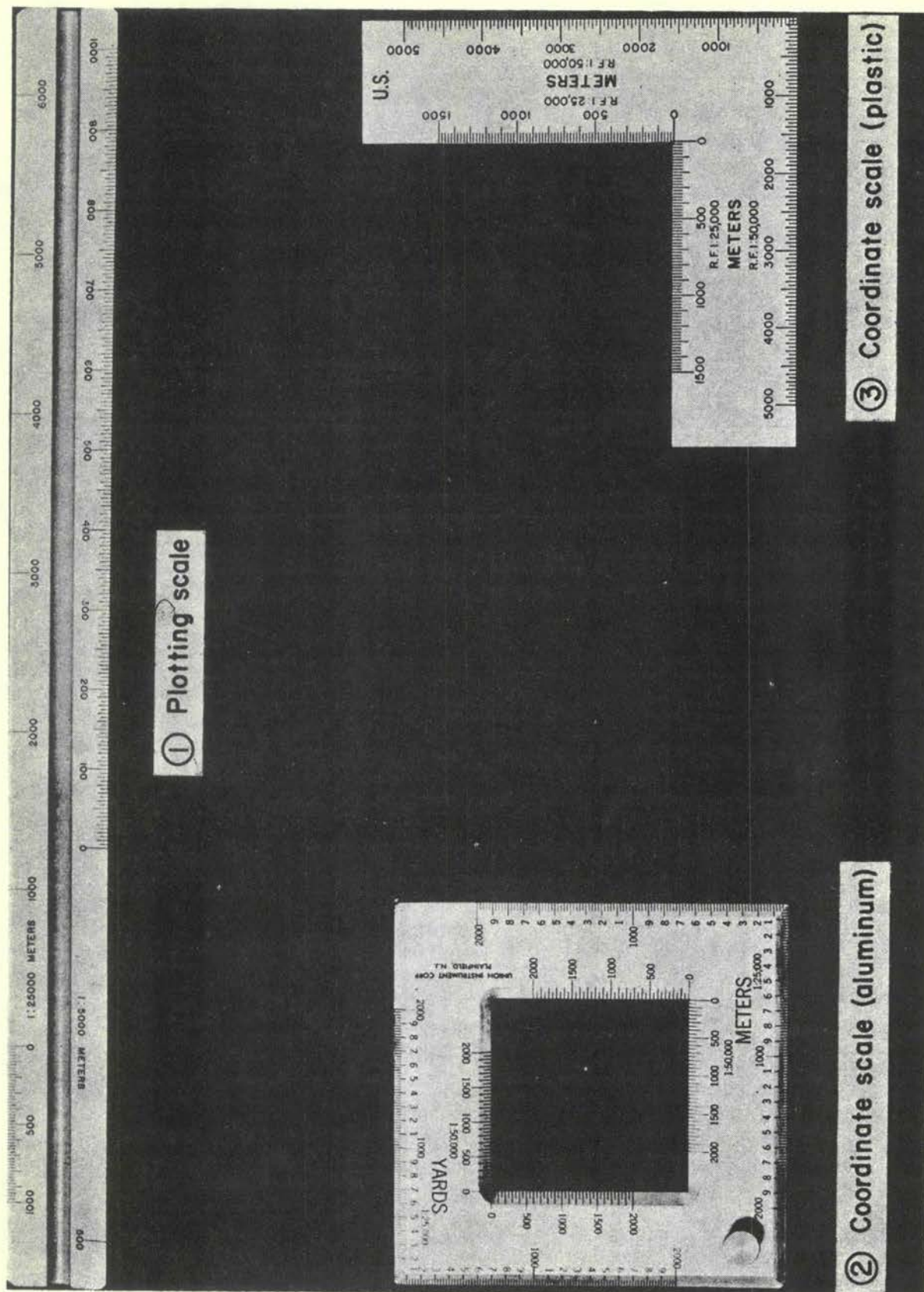


Figure 67. Plotting and coordinate scales.

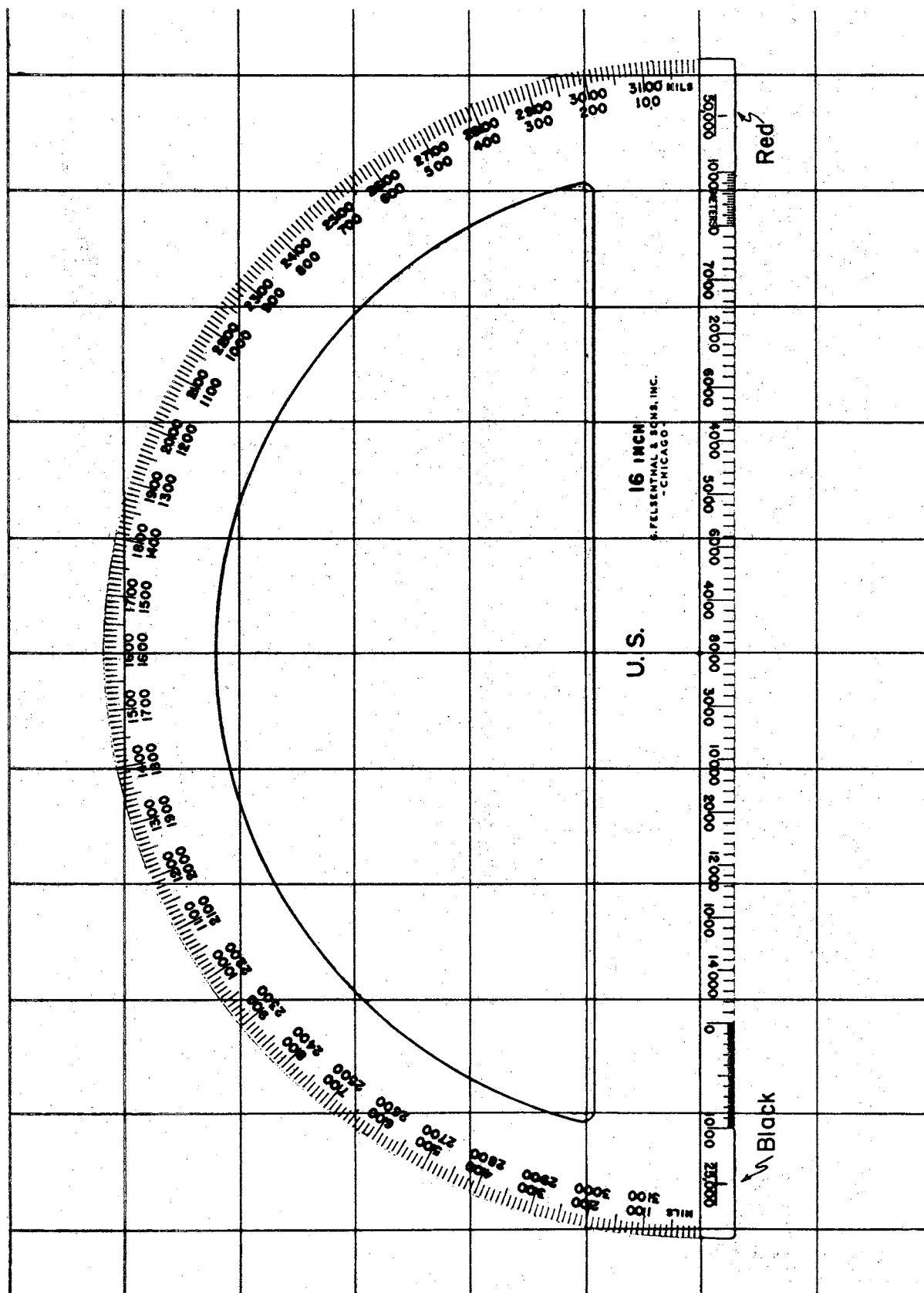


Figure 68. Protractor.

g. Protractor (fig. 68). The protractor is a plastic angle-measuring instrument made in the shape of a half circle. The arc in the half circle is graduated in 10-mil increments with each 100-mil graduation numbered in a clockwise and a counterclockwise sequence. The hairline connecting the 0- and 3,200-mil graduations is used as a baseline for measuring angles. The straightedge of the protractor is graduated in yards—1:25,000 scale (black) and 1:50,000 scale (red).

h. Range-Deflection Protractor (RDP)—(Aluminum) (fig. 69). The RDP is used to measure angles and distances. It is used to measure range and deflection from battery to the target and to polar plot. The left edge of the arm is graduated in meters (1:25,000 scale). The arc of the RDP covers 1,000 mils and is graduated in 5-mil increments with each 50-mil increment indicated by a long line.

i. Graphical Firing Table (GFT) Fan (fig. 70). The GFT fan is a device for determining firing data and for measuring angles and distances. The complete GFT fan consists of the base, ballistic scales, and cursors. The base is similar to the range-deflection protractor described in *h* above. The arm of the base has studs over which the ballistic scale may be fitted. Each ballistic scale contains a range scale along its left edge and opposite each range certain ballistic data appropriate for that range. Each cursor is constructed so that, when properly seated on the ballistic scale, the left edge of the fan will rest against the map pin in the point to which data are being measured, and the hairline of the cursor will be exactly opposite the pin. Range and appropriate ballistic data may be read under the hairline.

258. Tick Marks

a. Tick marks are symbols used to mark the pin holes which represent the location of installations and targets plotted on a firing chart. The tick marks are straight lines, 90° apart, starting approximately 40 meters from the pin hole and extending approximately 150 meters (1:25,000 scale). Normally, tick marks are drawn parallel to the grid lines. If the point plotted falls on, or very close to, a grid line, the tick marks are drawn at a 45° angle to the grid line. The tick marks are black (4H pencil)

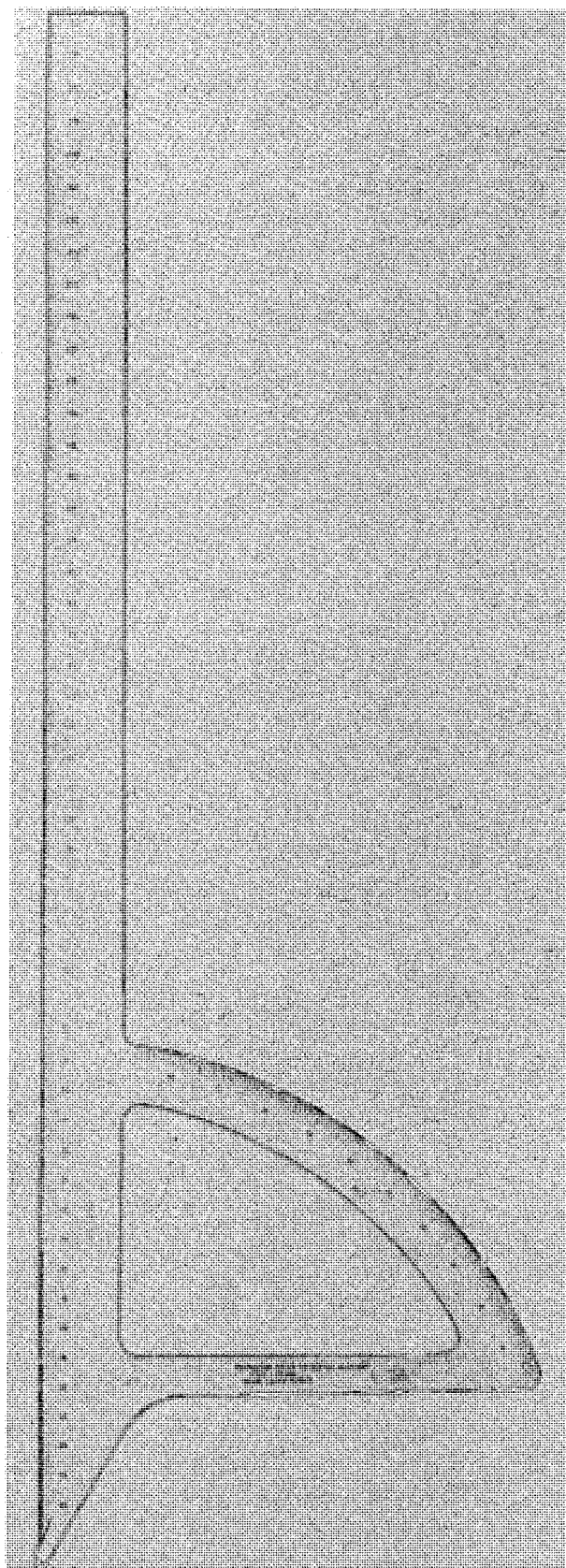


Figure 69. Range-deflection protractor (aluminum).

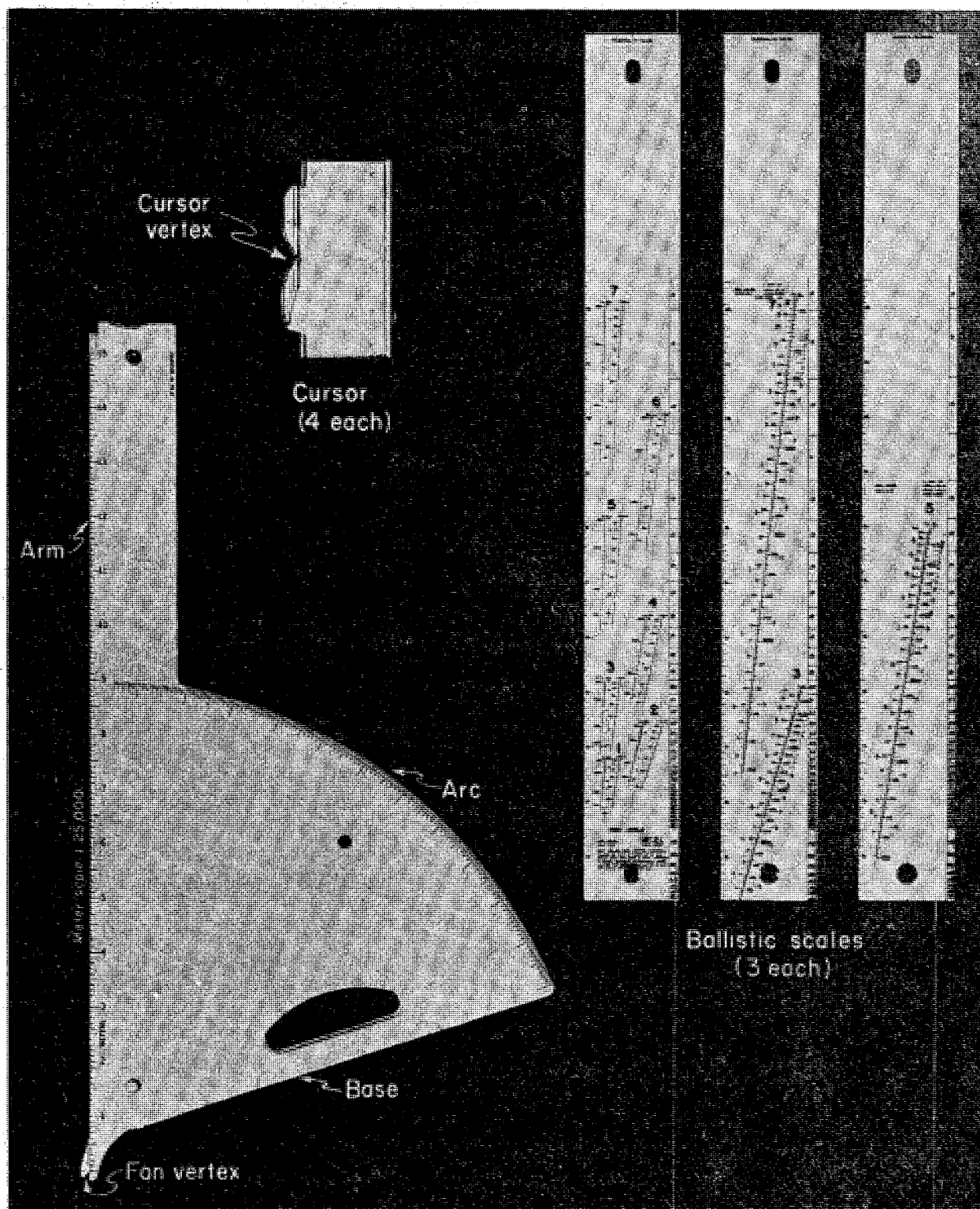


Figure 70. GFT fan.

for points which have been surveyed. When the point has been located only by firing, the tick marks are red.

b. The identification of the point is placed in the upper right quadrant of the tick marks in the following manner (fig. 71):

- (1) Battery: Letter designation in appropriate color; i.e., A—red, B—black, C—blue, D—orange.
- (2) Radar: Military symbol in green.
- (3) Forward observation post—military symbol plus the call number of the observer. (If the observer is from another unit, call sign and call number both will be used.)
- (4) Battalion observation post—letter designation plus the assigned number; e.g., 02.
- (5) Registration points—registration point plus the number assigned; e.g., Reg pt 3.
- (6) Concentrations (targets)—assigned concentration number; e.g., AD415.

c. The altitude in meters of the plotted point is placed in the lower left quadrant in black.

d. If the plotted point has been fired on, the fuze used in fire for effect may be placed in the lower right quadrant.

e. If the target has been fired on with high-angle fire, the letters "HA" may be placed in the upper left quadrant.

f. The charge fired may be placed in the upper left quadrant.

g. The pieces of an artillery battery are sometimes widely dispersed. Therefore, it may be necessary to plot the location of each piece or platoon center of each platoon.

259. Plotting a Point From Coordinates With a Plotting Scale

a. A normal grid is defined as a grid that is printed to the exact scale of the plotting scale (fig. 72). To plot a point, the coordinates of which are 6241938749, on a normal grid, place the 0 graduation of the plotting scale on the north-south line 62 and the 1,000-meter graduation on the north-south line 63. Placing the scale about 1 grid square above the approximate location of the point, mark 419 meters with a map pin. Move the scale about 1 grid square below the approximate location of the point and

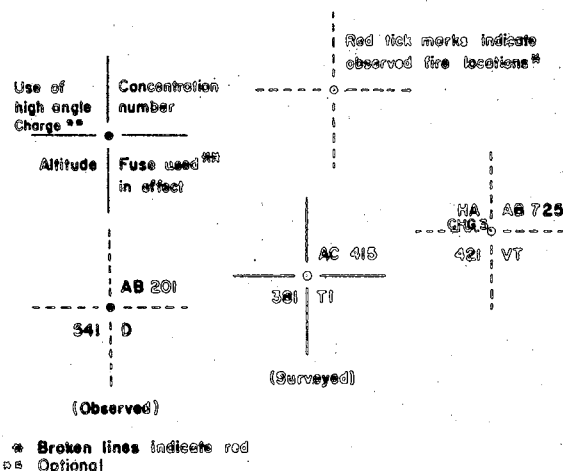


Figure 71. Marking plotted points.

repeat the operation. Connect the two map pins with a fine, light line by using a 6H pencil. This will be the north-south line passing through the point. In a similar manner, determine the east-west line passing through the point. The intersection of these lines is the desired point, which is indicated by a tick mark made with a 4H pencil.

b. Grid lines are sometimes closer or more distant than normal owing to poor manufacturing processes or the shrinking or stretching of the grid paper. When grid lines are closer than normal, plot the point in the same manner as described in a above, inclining the scale so that the 0 of the scale is on 1 grid line and the 1,000-meter graduation is on the other grid line. The point will then be plotted in its true relation to the grid, as the 100-, 10-, and 1-meter digits express the proportional part of the distance between grid lines (fig. 73).

c. If the grid lines are more distant than normal, measure the distance between the grid lines and find the difference from normal. The proportional part of this difference is added to a measurement. For example, if the distance between grid lines is measured as 1,020 meters, the difference from normal is 20 meters. The proportional part of this distance for a 400-meter measurement is $400/1000 \times 20$, or 8 meters. The 400-meter measurement then is scaled as 408 meters (1, fig. 74).

d. Similar results can be obtained by diagonally inclining the plotting scale so that the

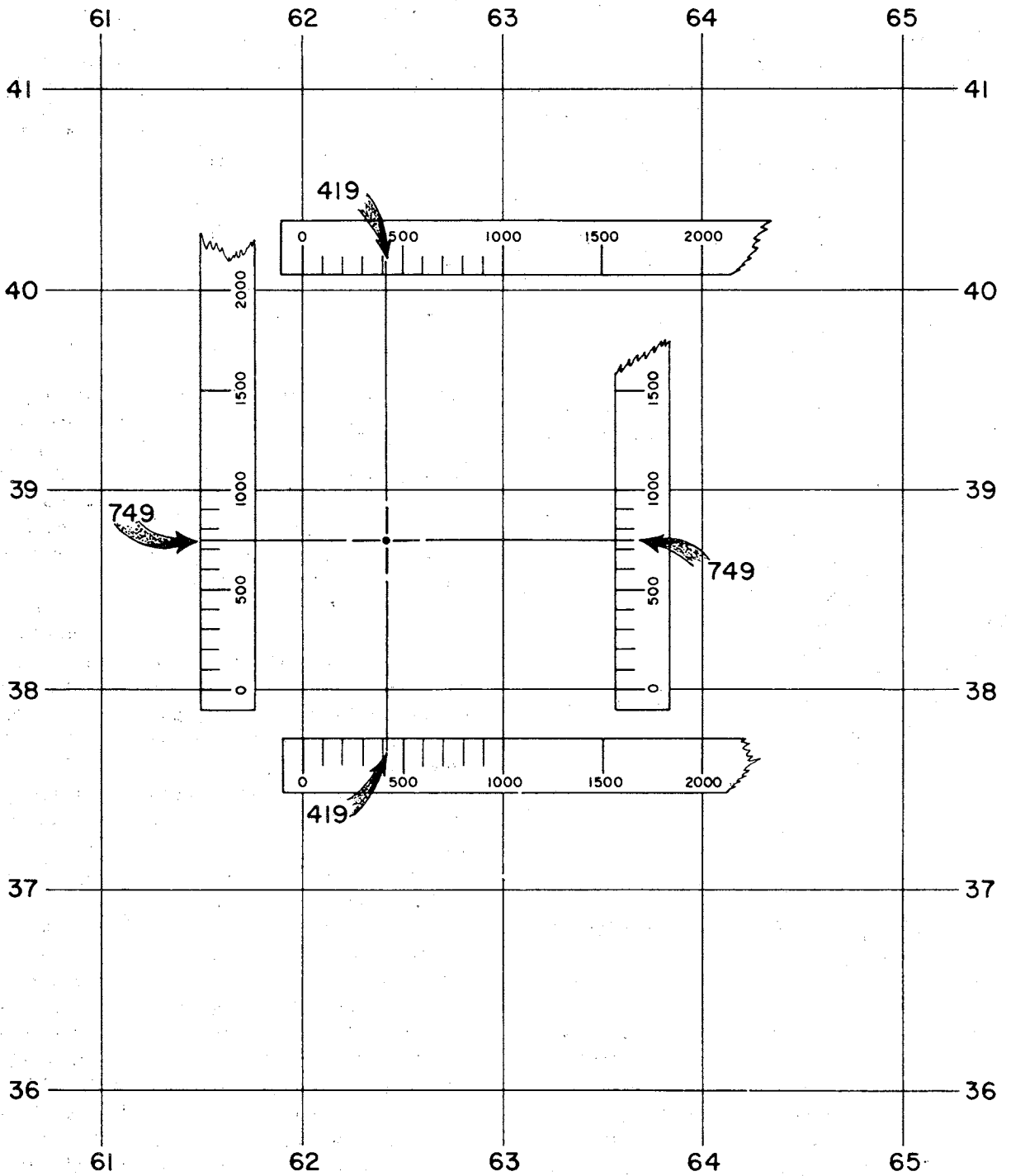


Figure 72. Plotting a point from coordinates on normal grid.

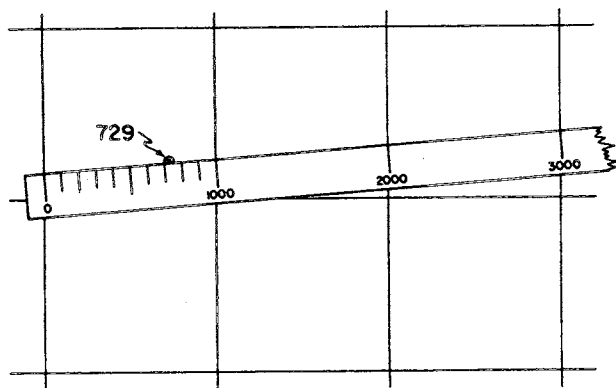


Figure 73. Plotting a point from coordinates when grid lines are closer than normal.

0 graduation is on one grid line and 2,000-meter graduation is on the adjacent grid line. The distance to be plotted is multiplied by 2, and that result is scaled. In 2, figure 74, in plotting the easting coordinate, the 400-meter measurement would be scaled as 800 on the inclined plotting scale.

260. Measuring Coordinates of a Point With a Plotting Scale

Coordinates are measured in the same manner as they are plotted and the distance is read directly between the point and the grid line. The first digit(s) of the easting coordinates is the number appearing at the top or bottom of the north-south line west of the point. The balance of the easting coordinate is the distance of the point east of this north-south line, as measured with the scale. For the northing coordinate, the first digit(s) is obtained from the right or left of the east-west line south of the point and the balance of the northing coordinate is the distance of the point north of this line as measured with the scale. If the grid lines are closer or further than normal, measurements are made in the same manner as they are in plotting points.

261. Use of Coordinate Scale

a. When rapid massing of fires on targets of opportunity is necessary, plotting may be done with the coordinate scale (2 and 3, fig. 67). To plot with the coordinate scale, first determine the grid square in which the point will fall. Always place one arm of the scale on the east-west grid line and the other arm toward

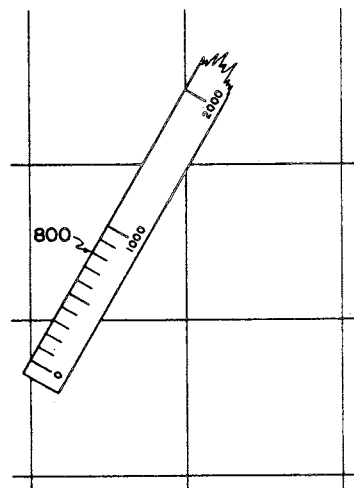
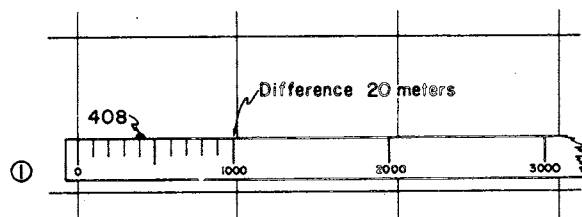


Figure 74. Methods of plotting points from coordinates when grid lines are more distant than normal.

the north. With the edge of the horizontal scale along the east-west grid line, slide the scale along this line until the distance to be plotted appears directly over the north-south line. Keeping the scale in this position, read up the vertical scale to the distance to be plotted and mark this point with a plotting needle. Since the coordinate scale has 1:25,000 and 1:50,000 scales, it is frequently desirable to place tape over the scale not in use to avoid using the wrong scale.

b. To measure the coordinates of a point, first determine the coordinates of the lower left-hand corner of the grid square containing the point. Place the coordinate scale at this grid intersection in the position mentioned above. Slide the scale to the right, keeping the edge of the horizontal scale along the east-west grid line until the point is reached by the vertical scale. Then read the distance east and north on the scales. Combine these two readings with the coordinates of the grid square to obtain the coordinates of the point.

262. Measuring and Plotting an Angle With a Protractor

To accurately measure or plot an angle with a protractor, the center of the protractor must be placed exactly over the vertex of the angle and the base line of the protractor placed exactly over one side of the angle. For greater accuracy, measure the angle with both sides of the protractor and take the mean of the readings. For example, measure first with the arc of the protractor to the right of the center and then with the arc to the left of the center. If there is a small difference between the readings, the mean will be used.

a. There are two ways of orienting the protractor to measure a grid azimuth. One method is to orient the protractor from a north-south grid line. The grid azimuth of a line can be measured by using as a vertex the intersection of the line with a north-south grid line. The protractor is placed so as to read the clockwise angle from the north-south grid line to the given line. If the arc of the protractor is right of the north-south grid line, the azimuth is read on the outer scale of the protractor. If the arc of the protractor is left of the north-south grid line, the azimuth is the value shown on the outer scale of the protractor plus 3,200 mils (1, fig. 75).

b. The grid azimuth of a line also may be measured by orienting the protractor from an east-west grid line and using the intersection of the line with an east-west grid line. Place the center of the protractor over the intersection and the 1,600-mil graduation of the protractor on the east-west grid line; the azimuth of the line is determined as in *a* above (2, fig. 75). If the grid azimuth is greater than 3,200 mils, the proper relation of the measured angle to 3,200 or 6,400 must be determined as in *a* above.

c. To draw a line of given azimuth through a point, the following procedure is used: Place the center of the protractor exactly over the point and the base line of the protractor roughly parallel to either an east-west or a north-south grid line. Rotate the protractor about the point until an east-west grid line (north-south grid line) cuts off the same amount of the arc on both ends of the protractor. The base line of the protractor is now parallel to the

east-west (north-south) grid line. If the point is so located that the grid lines cannot be used to orient the protractor, another point may be plotted with the same northing (easting) as the point. A line from the known point to the second point can serve as a line of known direction (east-west or north-south) for orienting the protractor. A line of given azimuth (or back-azimuth) is drawn by marking the given azimuth with a plotting needle at the circumference of the protractor and drawing a line through the known point and the marked point. In figure 76, the north-south grid line cuts the 160 mils of the arc from each end of the protractor. The line drawn has a grid azimuth of 5,630 mils. For plotting, if the base line of the protractor is always placed parallel to the north-south grid line, the correct azimuth of the plotted point is determined as described in *a* above.

263. Measuring and Plotting Distances With a Plotting Scale

The most accurate method of determining the distance between two points plotted on a firing chart is with the plotting scale. Care must be taken to use the correct scale on the plotting scale. After the direction of a line has been established on a chart, the length of this line may be plotted with the plotting scale.

264. Measuring and Plotting With a Range-Deflection Protractor (Aluminum)

a. When several angles and distances are to be plotted or measured from one point and one reference direction (i.e., polar plotting from radar, measuring range and deflection from the battery, etc.), the procedure is facilitated by the use of the range-deflection protractor.

b. Angles up to 1,000 mils can be measured conveniently with the range-deflection protractor. This measurement may be accomplished in the following manner:

- (1) Place the vertex of the RDP at the point from which the measurement is to be made.
- (2) Place the left edge of the arm of the RDP so that it coincides with the line which is the left limit of the angle to be measured and then place a pin at the rightmost graduation on the arc of the RDP.

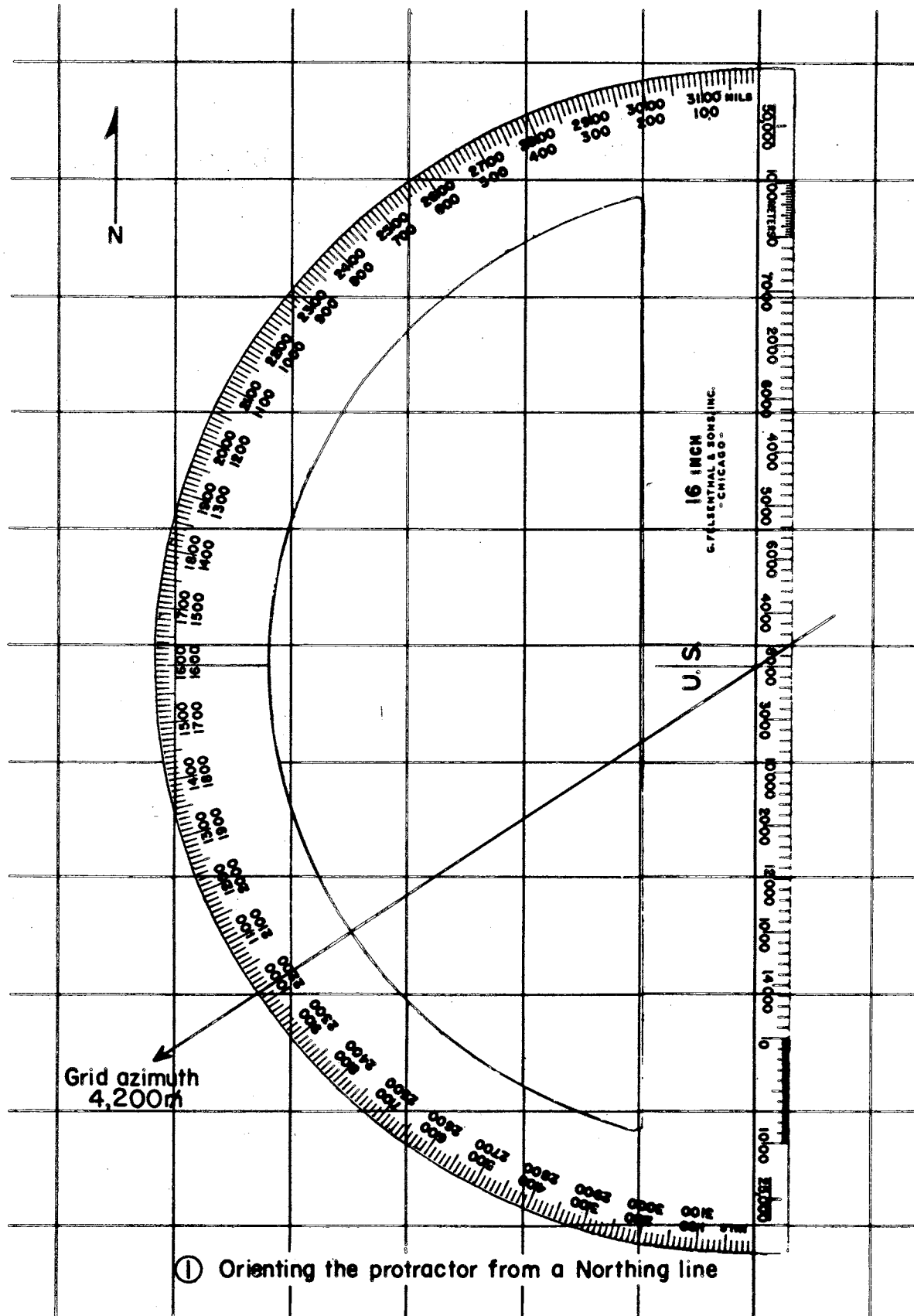


Figure 75. Methods of measuring grid azimuth with a protractor.

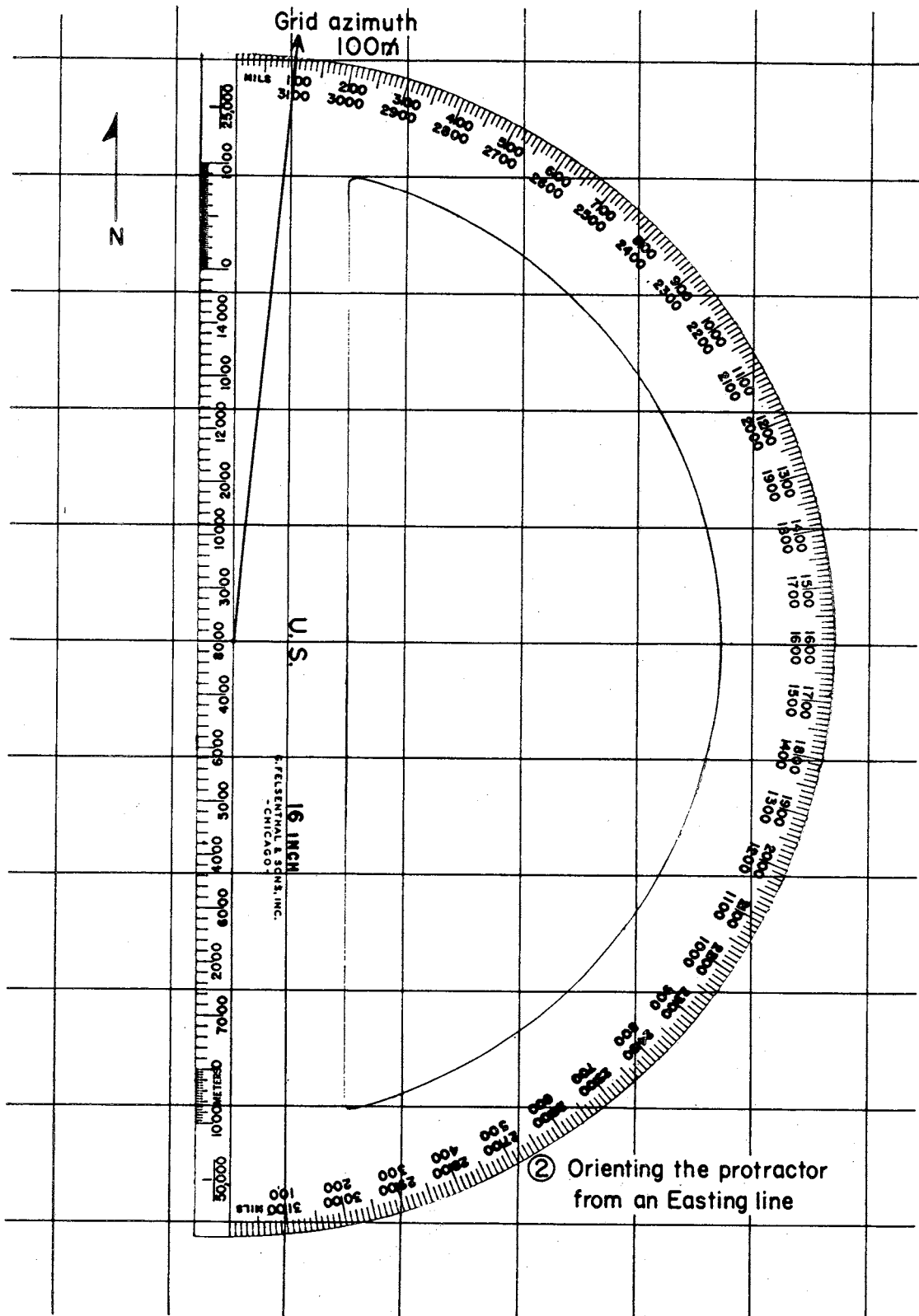


Figure 75—Continued.

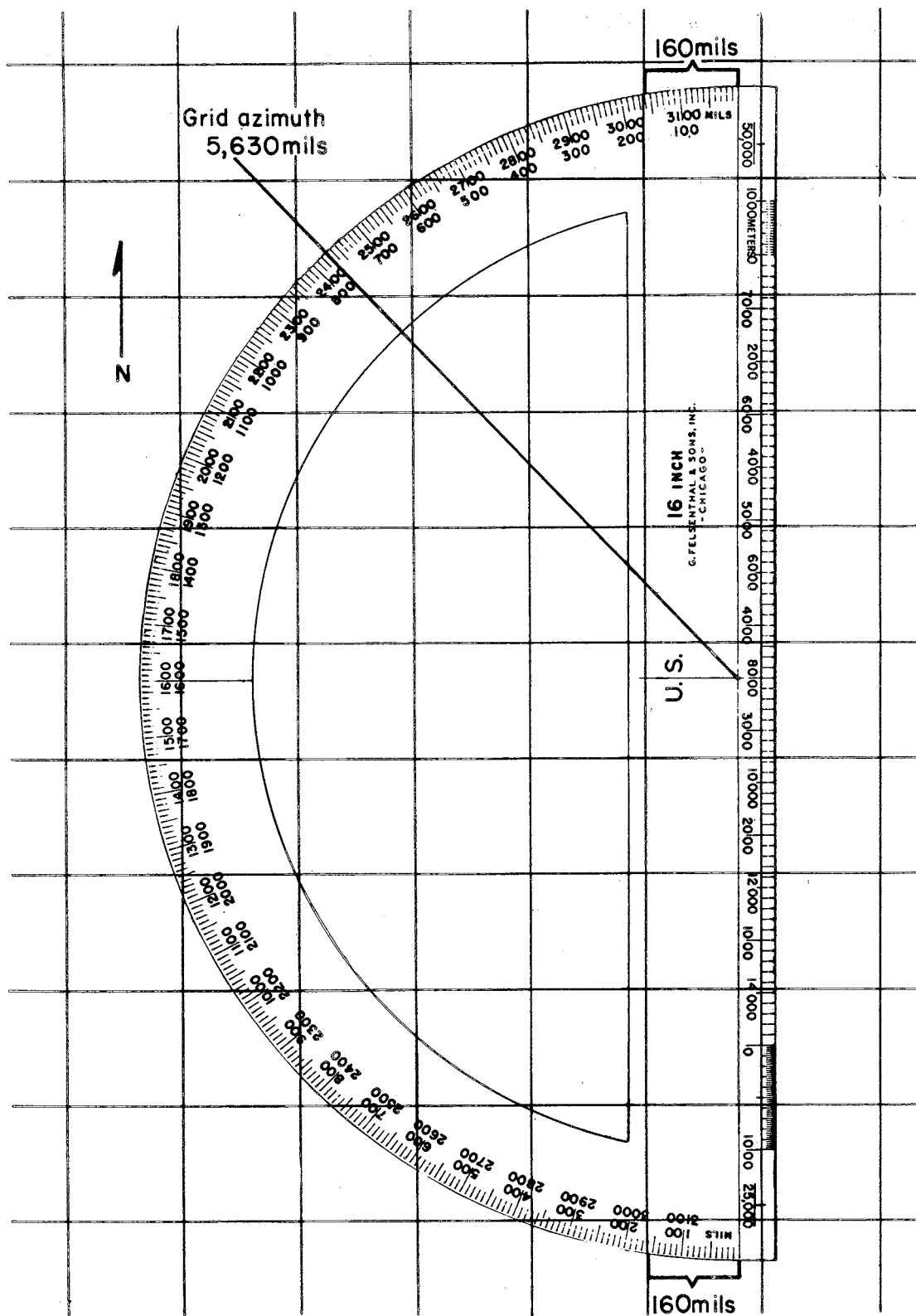


Figure 76. Method of drawing line of a given azimuth through a point.

- (3) Rotate the RDP until the left edge of the arm coincides with the line which is the right limit of the angle and read the value of the angle from the azimuth scale opposite the pin placed along the arc. (para. 265b & fig. 77.)

c. To measure the distance in meters between two points, place the vertex of the RDP at one of the points and the left edge of the arm against the pin in the second point and read the distance opposite the pin in the second point.

d. The procedure for plotting an angle is as follows:

- (1) Place the vertex of the RDP at the point from which the angle is to be plotted.
- (2) Place the left edge of the arm so that it coincides with the line from which the angle is to be plotted.
- (3) Place the pin opposite the leftmost graduation on the arc if the angle is to the left or opposite the rightmost graduation if the angle is to the right.
- (4) Rotate the RDP through the desired angle, using the pin as an index.
- (5) Place a pin against the left edge of the arm.
- (6) Draw a line from the vertex of the angle through the pin location.

e. If a large number of angles are to be measured or plotted from a point, the chart should be indexed and the arc of the range-deflection protractor should be marked in the manner described in paragraphs 265 through 268.

265. Preparing Charts With Polar Plot Indexes for a Range-Deflection Protractor

a. Points may be located by specifying the distance and direction from a point of known location. This method is known as location by polar coordinates, and the procedure for plotting a point so located is called polar plotting. The direction is usually stated as a grid azimuth. The known point is usually the location (plotted on the chart) of a radar set or an observation post (OP).

b. To facilitate the use of the range-deflection protractor for polar plotting, the 100-mil graduations on the arc are numbered, in black, as follows:

- (1) The rightmost graduation is marked zero (0).
- (2) Each succeeding 100-mil graduation is marked 1 through 9; the leftmost graduation is unmarked.

Note. Enough space should be left between the mil scale and these numbers for three other sets of numbers.

c. Azimuth indexes are constructed on the firing chart at 1,000-mil intervals covering the target area (fig. 77). These indexes are constructed so that the left edge of the arm of the range-deflection protractor is aligned on an azimuth which is a multiple of 1,000 when the appropriate index is opposite the rightmost graduation on the arc. To establish the appropriate azimuth indexes the following procedure may be followed:

- (1) Place the vertex of the RDP against a pin in the OP or radar position and the arm parallel to a convenient grid line. This establishes a reference line (not drawn) at an azimuth of 1,600, 3,200, 4,800 or 0 mils.
- (2) Place a pin opposite the azimuth corresponding to the last three digits of the direction in which the RDP is oriented. This value will be 600, 200, 800, 400, or 0, depending on the initial orientation of the RDP. The location of the pin represents an azimuth index of 1,000, 3,000, 4,000, 6,000, or 0 mils respectively. To locate azimuth indexes for 2,000 and 5,000, place a pin 1,000 mils right of the indexes for 1,000 and 4,000 respectively.
- (3) Move the RDP so that the left edge of the arm is against the *pin*, remove the pin and draw the azimuth index with a wedge-pointed 6H pencil. The index is a fine line approximately 2 inches long, extending 1 inch beyond and 1 inch short of the mil scale on the arc. The index is labeled with the appropriate identification (01, 31, radar symbol, etc.) and azimuth value

along the left side of the line, beginning approximately $\frac{1}{8}$ -inch beyond the mil scale. For radar, the lettering on the indexes is green; for observation posts, the lettering is black.

- (4) To establish an azimuth index 1,000 mils right (left) of a previously established index, place the leftmost (rightmost) graduation on the arc over the previously established index and then place a pin opposite the rightmost (leftmost) graduation. The index is then constructed at the pin location as in (3) above.

d. When the firing chart is indexed as in *c* above, and the arc of the range-deflection protractor is marked as in *b* above, the value of the azimuth measured or plotted is the sum of the azimuth marked on the azimuth index and the value read on the arc opposite that azimuth index.

266. Preparing Chart When Azimuth to a Known Point Has Been Reported From Radar Measurement

There will be occasions when the azimuth to a point plotted on the firing chart can be meas-

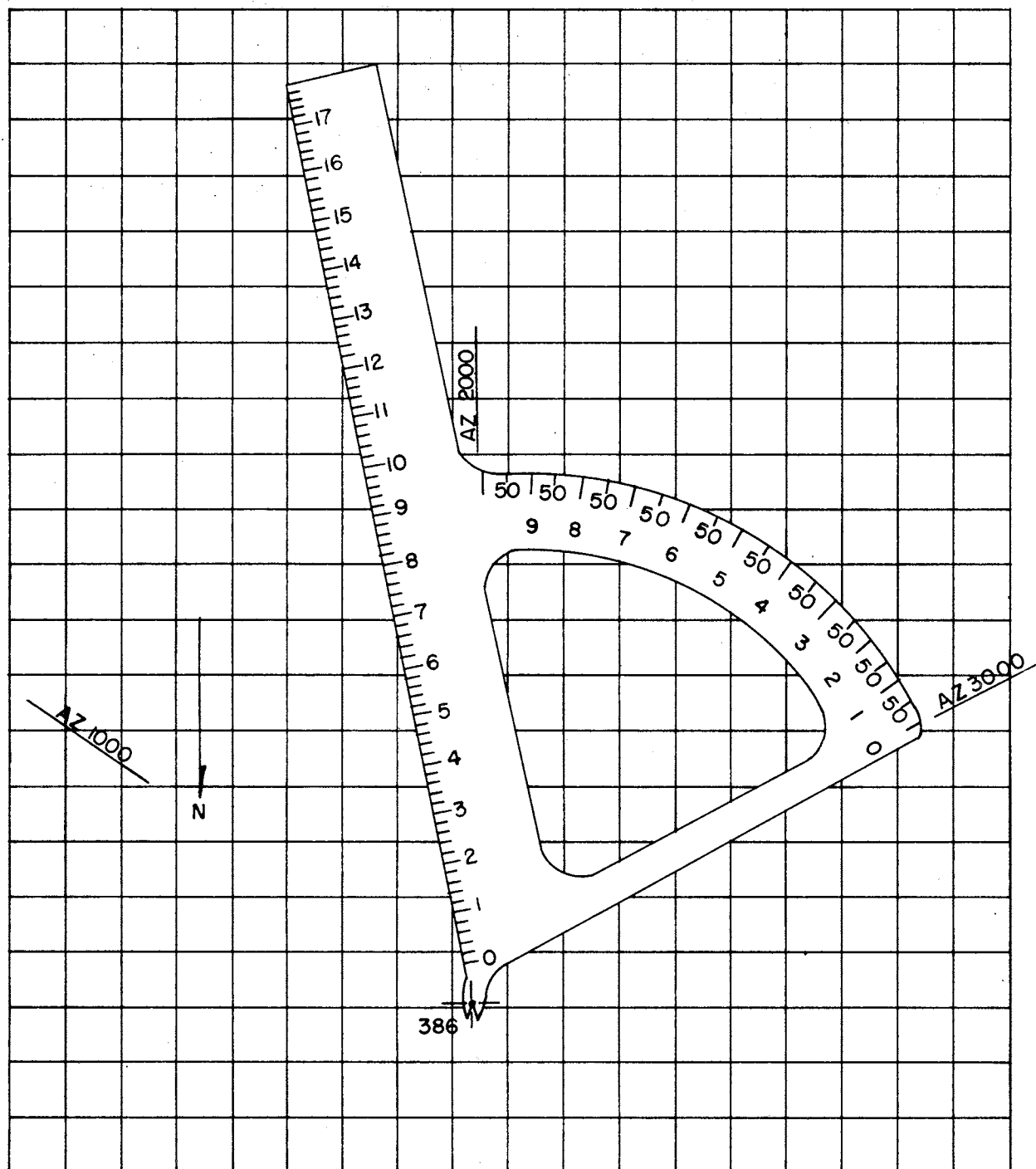


Figure 77. Range-deflection protractor and chart prepared for polar plotting.

ured by radar. In such cases the procedure shown below will be used to construct the azimuth index.

a. Place the vertex of the range-deflection protractor against the pin in the radar location and the left edge of the arm against a needle in the known point.

b. With the arc numbered as prescribed in paragraph 265b, place a plotting needle opposite the graduation on the arc which is equal to the reported azimuth minus the next lower 1,000 mils; e.g., if the reported azimuth is 4,350, place the needle opposite 350. The needle marks the location of the azimuth index for the next lower 1,000 mils; i.e., azimuth 4,000.

267. Plotting a Point Located by Polar Coordinates

The procedures used to plot a point located by polar coordinates from an OP (or radar) are as follows:

a. Place the vertex of the range-deflection protractor against the pin in the OP location with the arc over the proper OP azimuth index. There will be only one OP azimuth index which can be used to polar plot a given point. The index to be used is the one numbered with the multiple of 1,000 that is next lower than the azimuth reported by the observer.

b. Orient the range deflection protractor so that the azimuth on the index used, added to the value read from the arc opposite the index, is equal to the azimuth reported. This causes the left edge of the arm to be on the azimuth reported from the observation post.

c. Place a needle along the left edge of the arm at the reported distance (in meters) from the observation post.

Example: It is desired to plot a target at an azimuth of 1,960 mils and a distance of 10,700 meters from 01. Place the vertex of the range-deflection protractor against the pin in 01. Rotate the protractor until 960 on the arc is directly over the index marked Az 1,000. Without moving the protractor place a needle along the left edge of the arm at 10,700 meters from 01. The needle marks the location of the target.

268. Measuring and Plotting With a GFT Fan

The procedures described in paragraphs 264 through 267 for the use of the range-deflection protractor are applicable to the GFT fan.

269. Target Grid

a. *General.* The target grid is a device for converting, by plotting, the observer's target locations and corrections with respect to the OT (observer-target) line to target locations and corrections with respect to the GT (gun-target) line. A target grid is operated in conjunction with each of the charts in the battalion. An arrow extends across the grid, with the point of the arrow at the zero mark of the azimuth circle, and indicates the direction of the OT line. The azimuth scale is printed around the edge of the grid. The scale is graduated in a counterclockwise direction at 10-mil intervals from 0 to 6,400 mils, each 100 mils being labeled. The azimuth circle is numbered in a counterclockwise direction because the grid is rotated and the index is stationary. The scale of the target grid must be the same as that of the firing chart. When the target grid is used with a firing chart with a scale of 1:25,000, the smallest graduation of the grid represents a distance of 100 meters (fig. 78).

b. *Placing the Target Grid.* The center of the grid is placed over any point in the target area. This point may be the initial plotted location of the target to be adjusted on, a registration point, a met check point, a previously fired concentration, or an arbitrarily selected point such as a grid intersection. The selection of a point other than the target to be plotted must be such that the target falls beneath the grid. If subsequent corrections cause the target to plot off the grid, the grid is moved to a suitable new position and reoriented on the same azimuth given in the initial fire request.

c. *Orienting the Target Grid.* The chart operator constructs an azimuth index on the chart at the edge of the target grid to indicate north or zero azimuth. The index is located by rotating the grid until the arrow (or a line on the target grid parallel to the arrow) is seen to be parallel to a north-south grid line and the arrow

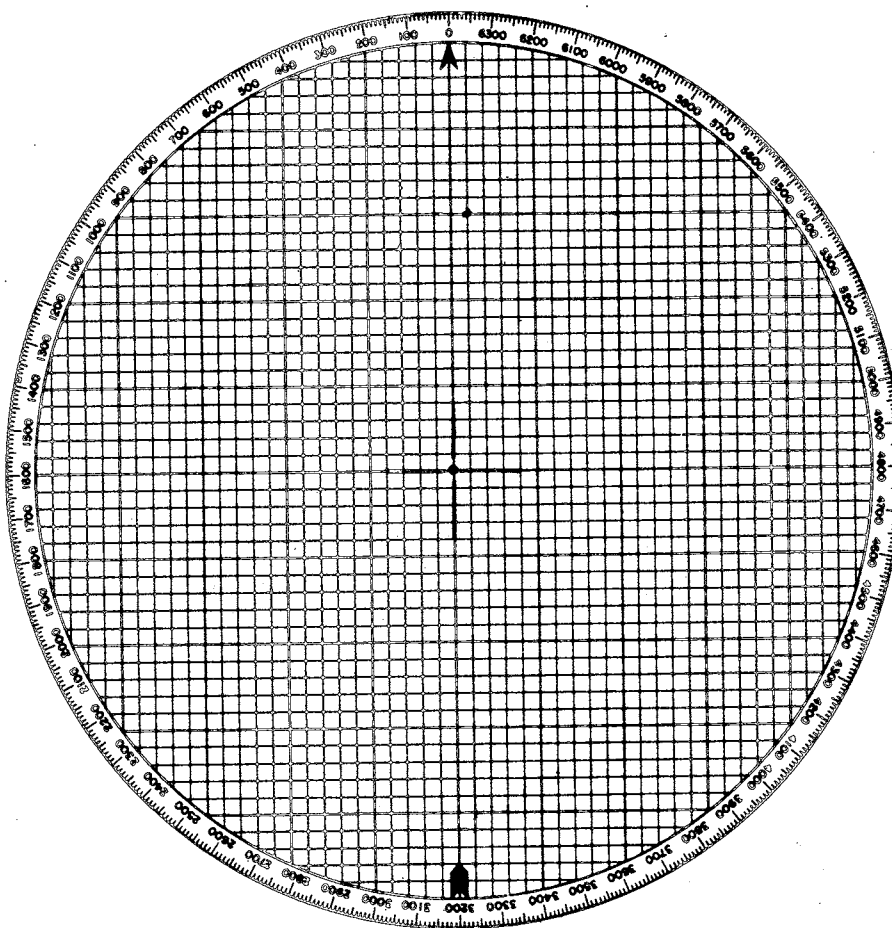


Figure 78. The target grid.

head is pointing north. The index is drawn on the chart at zero azimuth, extending 1 inch above and 1 inch below the edge of the target grid and plainly marked "N" to prevent its being confused with other indexes on the chart. Orienting the target grid is accomplished by rotating it until the figure read opposite the azimuth index is the same as the OT azimuth announced by the observer. This operation places the arrow and all lines parallel to it on the same azimuth as the OT line (fig. 79).

d. *Plotting a Target by Shift From Known Point.* The target grid is placed so that both the known point and the target are beneath the grid, and is then oriented on the azimuth given by the observer. The plotting needle is moved right or left of the known point along a line perpendicular to the arrow and forward or back along the lines parallel to it. Figure 79 shows the plot of an observer's initial fire re-

quest; e.g., FROM REGISTRATION POINT 1, AZIMUTH 4110, RIGHT 600, DROP 1000. In this manner, the observer's target location is plotted in reference to a known point with respect to the OT line.

e. *Measuring an Angle.* The target grid may be used to measure an angle when a high degree of accuracy is not required. To measure an angle, the center of the target grid is placed over the apex of the angle to be measured and the 0 of the azimuth circle is placed over the right side of the angle. The size of the angle is read at the point on the azimuth circle that is intersected by the left side of the angle.

f. *Marking the Target Grid.* To aid the chart operator in plotting, the target grid may be marked with a plus sign in the first and fourth quadrants, a minus sign in the second and third quadrants, an R to the right of the arrow near 4800 and L to the left near 1600 (fig. 79).

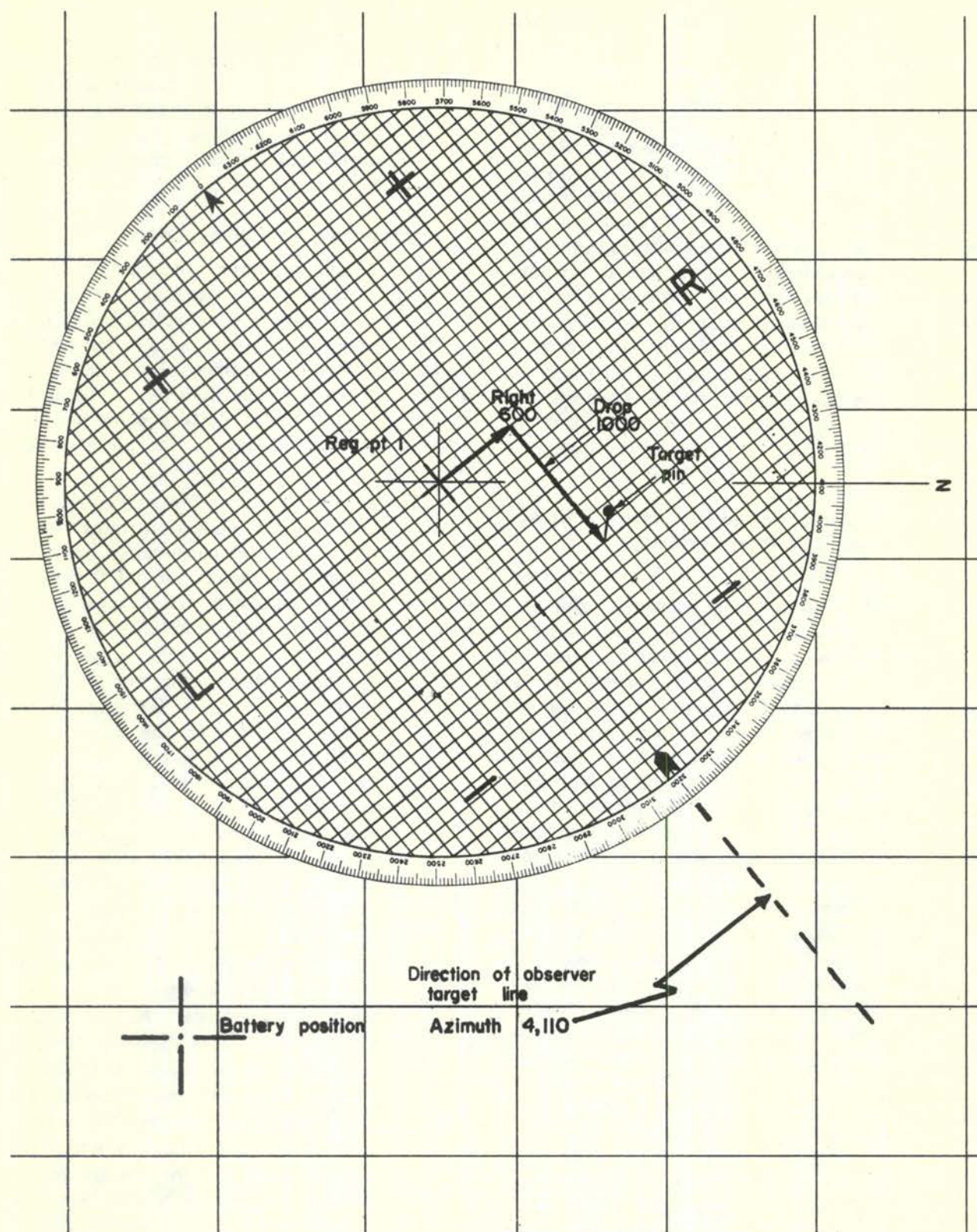


Figure 79. Plotting a target with the target grid by shift from a known point.

Section II. DETERMINATION OF CHART DATA

270. General

The purpose of a firing chart is to provide a graphic means for determining chart data. Chart data consists of the range (in meters), direction (deflection in mils), and vertical interval from the battery center to the target.

a. A *horizontal control chart* (usually a grid sheet) is used to determine the range and direction (deflection from the battery to the target). The range-deflection protractor is the device used to measure the range and deflection.

b. A *vertical control chart* (usually a grid sheet supplemented by a 1:50,000 map) is used to determine the vertical interval between the battery and the target. Range and direction may also be determined from the vertical control chart.

271. Numbering Range-Deflection Protractor (or GFT Fan) for Deflection (fig. 80).

a. Direction is normally measured and announced in terms of deflection. To facilitate the determination of deflection, the mil scale on the arc of the range-deflection protractor is numbered as follows: The center graduation on the arc is numbered with the deflection at which the aiming posts were placed when the battery was laid. The 100-mil graduations to the right of center represent an increase in deflection, those to the left represent a decrease in deflection. The rightmost graduation is not numbered. The numbers are written in black and the last two zeros are omitted; i.e., 2,900 and 3,000 are written as 29 and 30. With the arc marked with these figures only, deflections may be measured to targets 500 mils right and left of the direction in which the battery is laid.

b. To determine deflections for targets more than 500 mils right and left of the direction in which the battery is laid, additional numbers are placed on the arc of the fan as follows:

- (1) For targets that are from 500 to 1,500 mils right of the direction in which the battery is laid, the 100-mil graduations are numbered (in red) with numbers 1,000 mils less than the black figures (*a* above).

- (2) For targets that are from 500 to 1,500 mils left of the direction in which the battery is laid, the 100-mil graduations are numbered (in blue) with numbers 1,000 mils greater than the black figures (*a* above).

272. Preparing the Firing Chart

Before the firing chart can be used to determine chart data, the battery center must be plotted and a temporary deflection index must be constructed. When each piece or the platoon center is plotted on the firing chart, tick marks and temporary deflection indexes are identified by using the standard battery color code together with the number of the piece or platoon.

a. *Temporary Deflection Index.* Prior to registration, a temporary deflection index is constructed and is used in conjunction with the range-deflection protractor (or GFT fan) to determine chart deflection. This index is constructed in the following manner:

- (1) With the vertex of the range deflection protractor against the pin in the battery position, the left edge of the arm is oriented in the direction in which the battery is laid. If the battery is laid on a grid azimuth, the azimuth is plotted from the battery position. Using the technique described in paragraph 265c(1) and (2), place a pin in the chart to represent the azimuth corresponding to the largest multiple of 1000 contained in the azimuth of fire. (Do not draw an index since this is done only for OP's and Radar positions.) Move the RDP until the last three digits of the azimuth of fire, as read from the azimuth scale of the RDP, are opposite the pin. The left edge of the RDP is now oriented on the direction in which the battery is laid. If the battery is laid on the registration point, the left edge of the RDP is merely placed against the pin in the registration point.

- (2) A pin is now placed opposite the center graduation on the arc. The graduation will have already been numbered with the deflection at which the aiming posts were placed.
- (3) The left edge of the arm is placed against the pin, the pin is removed, and a fine line is drawn with a 6H pencil, 1 inch above and below the

arc. This line is the temporary deflection index. Mark the battery designation at the upper end of the index with a 4H pencil.

b. *Deflection Index.* Upon completion of registration the deflection index is constructed, and when necessary, supplementary deflection indexes are constructed 1000 mils right and left of the deflection index (para. 333).

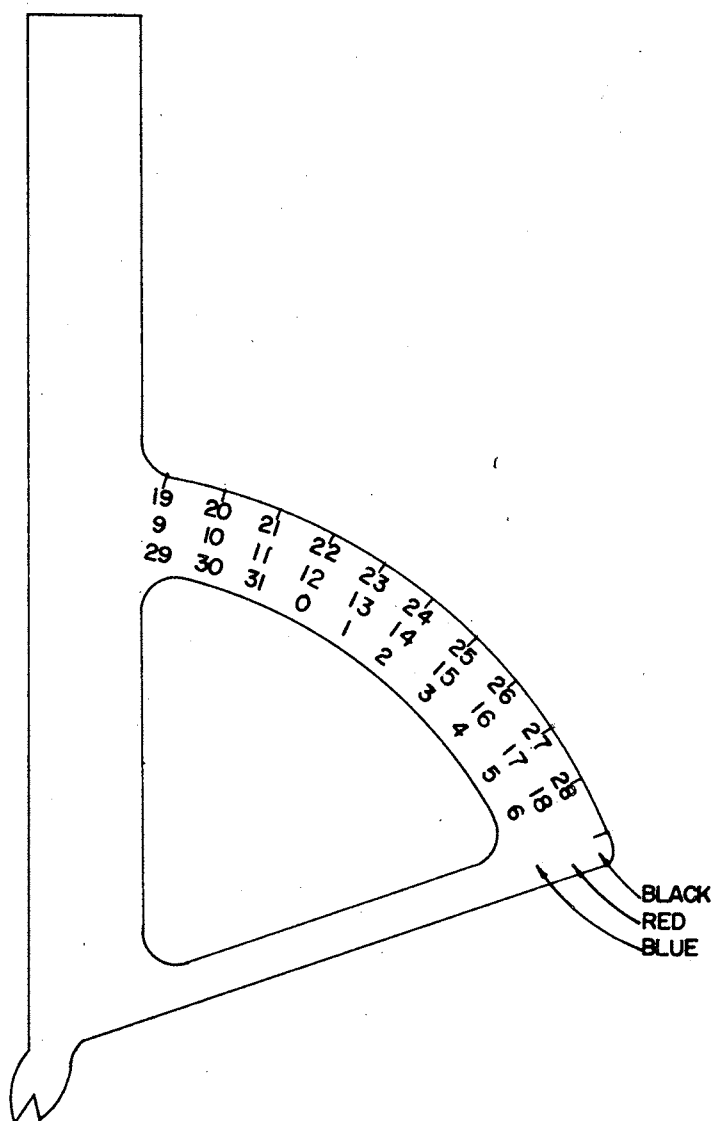


Figure 80. Range-deflection protractor numbered for measuring deflection.

273. Determination of Chart Deflection and Range

Chart deflection and range are measured in the following manner:

a. The vertex of the range-deflection protractor (or GFT fan) is placed against the pin in the battery position and the left edge of the arm against the pin in the target location.

b. Range in meters is read on the scale of the arm opposite the pin in the target location. Range is measured and announced to the nearest 10 meters.

c. The chart deflection is read on the arc opposite the deflection index to the nearest mil. When the index which appears at the arc is the deflection index, the black numbers are used. The red numbers are used with the right supplementary deflection index and the blue

numbers with the left supplementary deflection index.

274. Determination of Vertical Interval

The vertical interval between the battery and the target is determined in the following manner:

a. Determine the altitude of the target by—

- (1) Reading altitude from a map when the target is located by coordinates.
- (2) Applying the observer's vertical shift to the altitude of the point with reference to which the target is located.

b. Subtract the altitude of the battery from the altitude of the target. The result is the vertical interval. If the altitude of the target is greater than that of the battery, the sign of the vertical interval is plus. If the altitude of the target is less than the altitude of the battery, the sign of the vertical interval is minus.

CHAPTER 17

FIRING DATA

275. General

The data determined from the firing chart (deflection, range, and vertical interval) must be converted to settings to be placed on the cannon and ammunition in order that the projectile may hit the point to which chart data has been measured. Firing data are deflection, charge, fuze setting, and quadrant elevation.

276. Deflection

Firing deflection is the sum of the chart deflection (para. 273a and c) and the deflection correction, if any (para. 332).

277. Charge

For cannons that fire semifixed or separate loading ammunition, the amount of propellant may be varied. The propellant is packaged in increments, and the amount to be used is expressed in increments as CHARGE (so-and-so); e.g., charge 5 is increments 1 through 5. The selection of charge is discussed in paragraph 400c(7).

278. Elevation

a. In order that an artillery piece, firing a given charge, may cause a projectile to achieve a prescribed range, the tube must be raised from the horizontal to a vertical angle known as elevation. The elevation can be determined from the tabular firing tables, from a graphical firing table (GFT), or from a GFT fan.

b. In tabular firing tables, range is listed every 100 meters, and an elevation, valid under certain assumed standard conditions, is given for each tabulated range. Elevations corresponding to ranges between tabulated ranges are determined by interpolation.

c. On both the GFT and the ballistic scales of the GFT fan, elevation, valid under assumed standard conditions, is determined by placing the hairline of the cursor over the range in

question and reading the elevation under the hairline on the elevation scale.

279. Site

If the target (or desired point of burst) is at an altitude other than that of an artillery piece the trajectory may not pass through the target. To compensate for this difference in altitude an additional element of firing data called site is required. The term "site" as used in artillery denotes the algebraic sum of the angle of site plus the complementary angle of site. Site is the angle formed by the base of the trajectory and the line of sight.

a. Angle of Site.

- (1) The angle of site can be computed, by using the simple mil formula, $\eta = W/R$, when η is the angle of site, W is the vertical interval, in meters, between the battery and the target (point of burst), and R is the chart range to the nearest 100 meters in thousands (e.g. range 4060 meters is expressed as 4.1). Angle of site is computed to the nearest one-tenth mil.
- (2) Angles of site of 100 mils or less may be computed using the simple mil formula or the graphical site table (GST). Graphical equipment uses the more precise formula, $\eta = 1.0186 W/R$ (para. 282b).
- (3) Angles of site greater than 100 mils must be computed by using the formula, tangent of the angle of site equals the vertical interval divided by the chart range.

b. *Complementary Angle of Site (Comp Site)*. Comp site is computed by multiplying the angle of site $a(1)$ above by the complementary angle of site for a plus or minus 1-mil angle of site as appropriate (supplementary data, table G, of the tabular firing table). Comp site is computed to the nearest one-tenth mil.

c. *Determination of site.* Site may be determined by using the graphical site table (GST) (para. 282b).

280. Quadrant Elevation

Quadrant elevation is the sum of elevation and site and is announced in fire commands as QUADRANT (so much). Quadrant elevation may also be computed by adding angle of site to the elevation corresponding to range plus complementary range.

281. Fuze Setting

a. When time fuze is used, a fuze setting is made which will cause the fuze to function at the desired point on the trajectory. The fuze setting is a function of elevation plus complementary angle of site. When the complementary angle of site is small, fuze setting may be considered a function of elevation alone.

b. The fuze setting for fuze M500 and fuze M520 corresponding to the elevation (or elevation plus comp site) may be determined from the tabular firing tables or the GFT.

c. For time fuzes other than M500 and M520, the fuze setting is obtained by adding the correction determined from the tabular firing table to the time of flight corresponding to the elevation.

d. Fuze setting is announced as TIME (so much).

282. Graphical Tables

The basic source of ballistic data is the current tabular firing table for each cannon. The determination of firing data is simplified by the use of graphical tables. The most commonly used tables are the graphical firing table (GFT), the graphical site table (GST), and the ballistic scales for the GFT fan. The user must be certain that the graphical equipment he is using is based on the same data as the current tabular firing table. GFT's and GST's are labeled with the designation of the associated

tabular firing table; e.g., FT 155-Q-3. Ballistic scales are labeled with the cannon to which it applies and a date. The date must be the same or subsequent to the date of the associated tabular firing table.

a. *Graphical Firing Table* (fig. 81). The graphical firing table is used principally for determining elevations corresponding to ranges determined by using the range-deflection protractor. Each table consists of one or more rules and a cursor, which slides on the rule. A hairline on the cursor is provided for use as an index for reading data on the rule. The range scale is the basic scale on the graphical firing table. All other scales are plotted with reference to the range scale. Above the range scale are the drift/deflection correction scale and a scale printed in red, marked "100/R." Beneath the range scale are ballistic scales—from top to bottom they are elevation, fork, and fuze setting. On the dividing line between the EL scale and the FORK scale is a red segment indicating the range limits which normally should be fired with a particular charge. A red triangle on this line indicates a good range for computing meteorological corrections. For ammunition fuzes for time fire, the fuze setting at which the probable error in height of burst is 15 meters is indicated by a red triangular gagepoint extending above the heavy red line which separates the two charges. To the left of this gagepoint and also extending above the heavy red line is a second red triangular gagepoint which indicates the range at which the probable error in height of burst for the next lower charge is 15 meters. Normally, time fire with a particular charge should not be attempted at ranges exceeding that indicated by the red triangular gagepoint for that charge. When no corrections are known, elevation and other ballistic data corresponding to chart range are read under the hairline when the hairline has been placed over the determined range. Corrections determined from registration or other sources are applied as described in chapter 19.

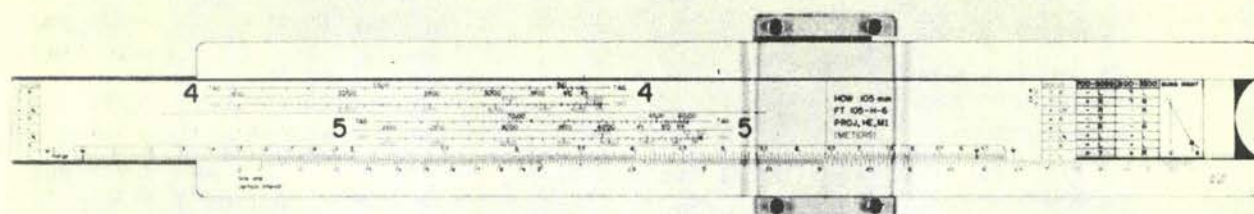


Figure 82. The graphical site table.

b. *Graphical Site Table* (fig. 82). The determination of site by use of angle of site and the complementary angle of site factor from the firing tables is time consuming. To facilitate computation, the graphical site table (GST) can be used to determine either angle of site or site. The GST can also be used to determine vertical interval when site or vertical angle and range are known. The GST consists of the base, which contains the D scale (site and vertical interval); a slide, which contains the C scale (range) which can be read in yards or meters, site-range scales for various charges in meters, and yard and meter gagepoints; and the cursor, which is a clear piece of plastic with a vertical hairline through the center. The C and D scales are identical to those on any slide rule and are used on the GST for determining angles of site of 100 mils or less or vertical interval when angle of site is known. (For angles of site greater than 100 mils, use the military slide rule and the tangent function.) For each charge, there are two site-range scales—one in red marked "TBG" (target below gun) and the other in black marked "TAG" (target above gun). The scales are so constructed and placed with respect to the C scale that when vertical interval (D scale) is divided by range on the site-range scale, complementary angle of site is included in the result (site). The TAG and TBG site-range scales differ by small amounts because the complementary angle of site factor for a minus angle of site differs from the factor for a plus angle of site. These scales are used in computing site or determining vertical interval when site is known. The meter (M) (when the vertical interval is in meters) or the yard

(YD) (when the vertical interval is in yards) gagepoint, rather than the normal index, is used for multiplication or division of the result by 1.0186 and, in effect, expresses the formula $m = 1.0186 W/R$ which is more precise than the mil relation formula $m = W/R$. (See the back of the GST for instructions on its use.) All newer GST models have a complete FDC sensing table beneath the slide except for the observer sensing column which is on both sides and at each end of the slide (fig. 82).

c. *Ballistic Scales, GFT Fan* (fig. 70). For each caliber of cannon, there is a ballistic scale for low-angle fire for each charge except charge 2. In addition, there is a ballistic scale for high-angle fire containing data for all charges. Each ballistic scale has one or more ballistic data lines for each charge plotted on the scale. In addition, each scale has a range scale graduated in meters on the left edge and a 100/R scale on the right edge. Data are also presented for drift, fuze setting, elevation, and fork. The scales and cursors can be removed from the fan. The cursor slides on the ballistic scale. A hairline on the cursor is used as an index for reading elevation, range, drift, fork, fuze setting, and 100/R pertaining to a given charge for a plotted location on the chart. Measurements are taken to the nearest mil or nearest 0.1 second. When no corrections are known, elevation and other ballistic data corresponding to the chart range are read under the hairline when the vertex of the fan is against the pin in the battery center and the cursor vertex is against the pin in the target location. When corrections have been determined from regis-

tration or other sources, they are applied as described in chapter 19.

d. Conversions of Yards to Meters.

- (1) The ballistic scales of the GFT fan have no provision for conversion of yards to meters.
- (2) The graphical firing table (GFT) has, at the left end of the red line dividing the range and elevation scales, two gagepoints labeled "M" and "YD" respectively (fig. 81). These gagepoints may be used to convert yards to meters as follows:
 - (a) Place hairline over M gagepoint.
 - (b) Construct a yard gageline on the cursor by drawing a fine line over the YD gagepoint.
 - (c) When range is known in yards, place the yard gageline over the distance in yards on the range scale.

- (d) The distance in meters and the corresponding elevation and fuze setting can then be read under the hairline.
- (3) The graphical site table (GST) has, at the left and right ends of the C (range) scale, yard and meter gagepoints labeled in red "YD" and "M" respectively (fig. 82). These gagepoints may be used to convert yards to meters as follows:
 - (a) Place the M gagepoint opposite the range in yards on the D (site and vertical interval) scale.
 - (b) Opposite the YD gagepoint, read the range in meters.
- (4) If it is desired to convert meters to yards; the procedures for the GFT and GST in (2) and (3) above are reversed.

CHAPTER 18

CONDUCT OF REGISTRATIONS

Section I. GENERAL

283. Introduction

If all conditions of materiel and weather were standard, firing a cannon at a particular elevation would cause the projectile to travel a distance shown in the firing table corresponding to that elevation. Similarly, with the proper deflection set on the weapon (including the drift correction from the firing table), the projectile would burst on the gun-target line. However, standard conditions of materiel and weather seldom exist simultaneously; thus, the projectile will rarely hit the target when fired with standard data for the chart range and deflection. Survey, firing chart, materiel, and nonstandard atmospheric conditions may each contribute errors. The number of meters by which the projectile bursts over or short, right or left of the target is the combined effect of these errors. The magnitude of the cumulative error and the correction for that error can be determined by registration.

284. Types of Registrations

The types of registration are—

a. Precision Registration. Precision registration is a technique that determines, by adjustment the firing data that will cause the center of impact of a group of rounds to occur at a point of known location, called a registration point.

b. High-Burst and Center-of-Impact Registrations. A high-burst or a center-of-impact registration is a technique that determines the mean burst location of a group of rounds fired with a single set of data.

285. Purpose of Registrations

The purpose of a registration is to determine the firing data (called adjusted data) that will place the mean burst location of rounds fired with that data at a point of known location. Registration data is used to determine corrections which, when applied, will compensate for the cumulative errors contained in survey, the firing chart, materiel, and nonstandard atmospheric conditions (ch. 19).

Section II. PRECISION REGISTRATION

286. General

a. A registration point is a point in the target area, the location of which is known on the ground and on the firing chart, and on which a precision registration is conducted. If the target area is large, it may be desirable to use more than one registration point. Some of the characteristics of a good registration point are that it be—

- (1) Readily identifiable.
- (2) Located horizontally and vertically close to the center of the target area or zone of action.
- (3) Permanent or semipermanent in nature.

b. Only one piece, normally the base piece, is used to conduct a registration.

c. DA Form 6-12 (Record of Precision Fire) is the form used by fire direction personnel to compute and record data during a precision registration.

d. A precision registration is conducted in two phases—adjustment and fire for effect.

287. Adjustment Phase

a. The observer is normally directed to conduct a registration on a designated registration point. Occasionally, the observer may be required to select a registration point.

b. On receipt of the observer's initial fire request, the horizontal control operator (HCO)

determines and announces the chart range and deflection to the registration point. The vertical control operator (VCO) computes and announces site. The initial fire commands are determined by the computer and sent to the battery. Fuze quick is used throughout the adjustment.

c. The HCO plots the observer's subsequent fire requests, using the target grid, and announces chart data. The computer determines and announces the subsequent fire commands.

d. When the observer's correction is ADD (so much) or DROP (so much) and does not include a deviation correction, an observer deviation sensing of LINE is presumed at FDC and an FDC deflection sensing is determined and recorded. FDC deflection sensings determined during the adjustment may be used during fire for effect to establish one limit of a deflection bracket.

e. The adjustment phase is ended when—

- (1) The observer splits the proper bracket.
- (2) A target hit occurs.
- (3) A sensing of RANGE CORRECT is made by the observer.

288. Determination of Angle T

a. The angle T is the angle formed at the target by the intersection of the gun-target line and the observer-target line.

b. At the beginning of a precision registration on a surveyed registration point, the HCO measures and announces the angle T to the nearest 10 mils. Normally, the announcement of the value of the angle T is made after the computer has sent the initial fire commands to the firing battery.

c. If the location of the registration point is not accurately known (i.e., when an observed firing chart is used), the value of the angle T is determined upon entering fire for effect.

d. If the target grid is centered over the registration point and oriented on the observer's azimuth, the angle T is measured by placing the vertex of the range deflection protractor against the battery pin and the left edge of the arm against the pin in the registration point. The value of the angle T is determined

from the azimuth scale of the target grid between the point where the arm of the range-deflection protractor intersects the scale and 0 or 3200, whichever is appropriate.

e. The angle T may be computed by comparing the observer's azimuth and the azimuth from the battery to the registration point.

289. Fire for Effect Phase

a. Fire for effect is begun when the adjustment phase has ended. During fire for effect, the firing chart is not used. Firing data are computed from the observer's sensings.

b. Fire for effect is conducted with fuze quick until the correct deflection and adjusted elevation are obtained. When desired, a time registration is conducted with fuze time to determine the adjusted time (para 298-300).

290. Determination of FDC Sensings

Adjusted elevation and the correct deflection are determined with respect to the GT line. Observer sensings, made with respect to the OT line, must be converted to FDC sensings with respect to the GT line. The FDC sensing corresponding to a given observer sensing is dependent on the location of the observer with respect to the GT line (right or left) and the size of the angle T. An FDC sensing table (fig. 83) is provided to facilitate the determination of FDC sensings.

291. Factor S

a. The factor S is the deflection change in mils between two rounds that bracket the target and are 100 meters apart on the observer target line (fig. 84). The value of the factor S depends on the range and the size of the angle T. A decrease in range will increase the factor S. An increase in the size of angle T will also increase the value of the factor S.

b. When the observer obtains a 100-meter bracket on the OT line, it is assumed that a 1 S deflection bracket exists. When the 100-meter bracket is split, the deflection read by the HCO should be within $S/2$ of the correct deflection.

c. The values of $S/2$ for all likely combinations of range and angle T have been computed

FDC SENSING											
Guns on left	Observer Sensing	1 -99m	100 -499m	500 -799m	800 -1399m	1400 -1600m	1601 -1799m	1800 -2399m	2400 -2699m	2700 -3099m	3100 -3200m
	?R	?R	+R	+?	+?	+?	+?	+?	+?	+L	?L
	?L	?L	-L	-?	-?	-?	-?	-?	-?	-R	?R
	+LN	+L	+L	+L	+L	+L	-L	-L	-L	-L	-L
	+R	+R	+?	+?	+?	+L	+L	?L	-L	-L	-L
	+L	+L	+L	+L	?L	-L	-L	-?	-?	-?	-R
	-LN	-R	-R	-R	-R	-R	+R	+R	+R	+R	+R
	-R	-R	-R	-R	?R	+R	+R	+?	+?	+?	+L
	-L	-L	-?	-?	-?	-R	-R	?R	+R	+R	+R

FDC SENSING											
Guns on right	Observer Sensing	1 -99m	100 -499m	500 -799m	800 -1399m	1400 -1600m	1601 -1799m	1800 -2399m	2400 -2699m	2700 -3099m	3100 -3200m
	?R	?R	-R	-?	-?	-?	-?	-?	-?	-L	?L
	?L	?L	+L	+?	+?	+?	+?	+?	+?	+R	?R
	+LN	+R	+R	+R	+R	+R	-R	-R	-R	-R	-R
	+R	+R	+R	+R	?R	-R	-R	-?	-?	-?	-L
	+L	+L	+?	+?	+?	+R	+R	?R	-R	-R	-R
	-LN	-L	-L	-L	-L	-L	+L	+L	+L	+L	+L
	-R	-R	-?	-?	-?	-L	-L	?L	+L	+L	+L
	-L	-L	-L	-L	?L	+L	+L	+?	+?	+?	+R

Figure 83. FDC sensing table.

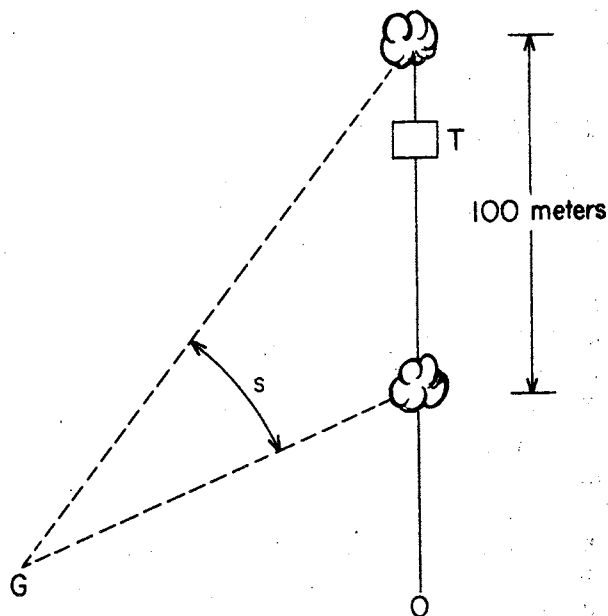


Figure 84. The factor S.

and placed in the S/2 table (fig. 85). The values of S/2 in the table is the computed value rounded to 2 or the nearest power of 2.

d. The S/2 may be determined as soon as the angle T for the mission is determined.

GT range in meters	S/2 TABLE				
	Angle T in mils				
	0-99 3100-3200	100-499 2700-3099	500-799 2400-2699	800-1399 1800-2399	1400-1600 1601-1799
2000	2	4	8	16	16
3000	2	4	8	8	16
4000	2	2	4	8	8
5000	2	2	4	8	8
6000	2	2	4	4	8
7000	2	2	4	4	4
8000	2	2	2	4	4
9000	2	2	2	4	4
10000	2	2	2	4	4
11000	2	2	2	4	4
12000	2	2	2	2	4
13000	2	2	2	2	4
14000	2	2	2	2	2
15000	2	2	2	2	2

Figure 85. S/2 table.

292. Correct Deflection

a. Deflection is correct when one of the following conditions has been satisfied:

- (1) A target hit is obtained.
- (2) A 2-mil deflection bracket is split.
- (3) Deflection sensings of left and right are obtained from the same deflection setting.
- (4) Deflection sensings of left and right are obtained from deflection settings 1 mil apart. (The last deflection is considered correct.)

b. The correct deflection is not necessarily the adjusted deflection (para 331).

293. Deflection in Fire for Effect

a. Deflection is not changed during fire for effect when the FDC deflection sensing is DOUBTFUL, except in the situation described in *e* below.

b. When a positive FDC deflection sensing is obtained, previous FDC deflection sensings, including any obtained during adjustment, are examined to determine if a deflection bracket exists.

c. If a deflection bracket exists, the bracket is split or the deflection is changed S/2 in the appropriate direction, whichever is the smaller change.

d. If no bracket exists, the deflection is changed S/2 in the appropriate direction.

e. If the adjusted elevation has been obtained but the correct deflection has not been determined, fire for effect is continued, at the adjusted quadrant elevation, and the observer is required to give range and deviation sensings in meters. After two successive FDC sensings of doubtful and based upon information from the observer—

- (1) The deflection may be considered correct.
- (2) An arbitrary shift may be made. Frequently the arbitrary shift will yield a positive FDC deflection sensing.

Note. See paragraph 299 for time registration.

f. After obtaining an adjusted elevation but not a correct deflection, the center of a 4-mil deflection bracket may be accepted as correct when—

- (1) Observed fires only are to be used.
- (2) Speed, not refined accuracy, is critical.

g. It is not infrequent that the terrain and other circumstances, such as the size of the angle T, dispersion, and the smallness of the registration point, will combine to present difficulties in the adjustment of deflection. In this instance, as in any other observed fire situation, the observer may be the best qualified to take action. The observer may see more than he can convey in the normal sensing. The S3 must be prepared to ask for and rely on the observer's report and judgment.

294. Fork

The fork is the change in elevation required to move the center of impact of a group of rounds a distance equal to 4 range probable errors. In a precision fire mission, the fork used is that corresponding to the first elevation fired in the fire for effect phase. If the value of the fork is an odd number, it is increased to the next higher even value to facilitate splitting. (The correct value of the fork must be used in the computation of the adjusted elevation.)

295. Elevation in Fire for Effect

a. The first round in fire for effect is normally the result of an observer's correction of ADD or DROP 50, FFE. Based on the FDC range sensing of this round, the S3 will change the quadrant elevation by moving one even fork in the opposite direction and firing one round. This procedure is repeated, if necessary, until a fork bracket is established. This bracket is then split and firing continued until three positive FDC range sensings are obtained. Positive sensings are OVER and SHORT. The quadrant elevation is then changed 1/2 fork in the direction opposite to the preponderance of the sensings. This will result in firing at one of the quadrant elevations which established the even fork bracket. Fire for effect is continued until two more positive range sensings are obtained for a total of six.

b. The six rounds considered in the computation of the adjusted quadrant elevation are the three rounds which yielded positive sensings, at the center of the bracket, the last two rounds which yielded positive sensings, and the round which established the even fork bracket and was fired at the same quadrant elevation as the last two rounds.

296. Computation of Adjusted Elevation

a. The computation of the adjusted elevation is based on the assumption that the six rounds considered fell in a normal dispersion pattern. The location of the center-of-impact of the six rounds with respect to the registration point may be computed based on the laws of probability and the size of the range probable error. A change in elevation that will place the center-of-impact at the registration point is computed.

b. The following formula is used to determine change to move the center-of-impact to the registration point:

$$\text{Elevation change} = \frac{\text{Difference in number of overs \& shorts}}{2 \times \text{number of rounds considered}} \times \text{fork}$$

Example: The six FDC range sensings obtained during fire for effect are four SHORTS and two OVERS. The fork is 6.

$$\text{Elevation change} = \frac{2}{2 \times 6} \times 6 = 1.0 \text{ mils. The sign of the change is plus if the preponderance is short and minus if the preponderance is over.}$$

change is plus if the preponderance is short and minus if the preponderance is over.

c. The elevation change is applied to the mean of the quadrant elevations used during fire for effect, and the result is expressed to the nearest mil. Site is then subtracted from the adjusted quadrant elevation. The result is the adjusted elevation.

Example: During fire for effect, three FDC sensings were determined at quadrant elevation 316 and three at 313. The elevation change is applied to quadrant elevation 314.5

(316 + 313). The adjusted quadrant is $\frac{316 + 313}{2}$ (314.5 + 1.0 = 315.5 = 316). Site is +3 mils; the adjusted elevation is 313.

297. Example of a Precision Registration

a. Figure 86 contains an example of a precision registration with fuze quick. The registration was conducted with a 155-mm howitzer (M109), using charge 4GB.

b. *Comment 1.* After the initial round is fired, the HCO measures and announces the angle T as, ANGLE T 430, GUNS ON THE LEFT. The computer then enters the S/2 table at chart range (to the nearest listed value, 5000) and the angle T (100-499) and determines the S/2 to be 2 mils.

c. *Comment 2.* Firing data for rounds 1 through 4 are based on the HCO's plotting of the observer's fire requests.

d. *Comment 3.* The observer's correction of ADD 100 from round 2 indicates that his sensing must have been SHORT LINE. Based on this observer sensing, an FDC deflection sensing of RIGHT is determined and recorded for round 2.

e. *Comment 4.* The value of the fork is determined at the first elevation in fire for effect. 303 mils (QE 309—Site + 6 = 303). Fork is 4 and 1/2 fork is 2.

f. *Comment 5.* The fourth round (first round in fire for effect) yields a positive FDC range sensing of OVER, therefore the fifth round is fired at a quadrant elevation four mils lower (one even fork). This round yields a SHORT, thereby establishing the even fork bracket on the gun-target line. The bracket is split and rounds 6, 7, and 8 yield a preponderance of SHORT, (—, +, —). The quadrant elevation is changed 1/2 fork opposite the preponderance, towards the OVER at quadrant elevation 309. Rounds 9 and 10 yield two more OVERS. The adjusted quadrant elevation and adjusted elevation are computed with the three rounds fired at quadrant elevation 307 and the three rounds fired at quadrant elevation 309.

RECORD OF PRECISION FIRE (FM 6-40)											
Date and time 22 MAR 65		Observer BLACK PENCIL 44		Adjusting point REG PT 1		Battery A					
GFT setting GFT A :chg 4 :lot RS :rg 5090 :el 301 :ti						Deflection correction R17					
Chart data		Initial fire commands									
Deflection 3215		Corr 0								BP Adjust	
Range 5090		EI 313								Sh HE Lot RS	
Adjusted data		Si +6								Chg 4 Fz 9	
Deflection 3198		S/2= 2								MF BP ①	
Elevation 301		F= 4		Df 3215		Angle T 430					
Time		F/2= 2		QE 319							
Round no	Chart df	Df fired	Chart range	Time fired	EI or QE fired	Observer sensing or corrections	FDC sensings				
							Range	Deflection			
①	3215		5090		319	R50-200					
②	3198		4930		306	+100		R			
③	3198		5020		313	L20-50FFE					
④	3197		4970		309	+R	+	?			
⑤		(3197)			305	-L	-	?			
⑥		(3197)			307	-R	-	R			
⑦		3199			307	+LN	+	L			
⑧		(3198)			307	-L	-	CORR			
⑨	BP ②				309	+R	+				
⑩						PR	+				
11					EM						
12	MEAN QE = $\frac{307+309}{2} =$				308.0						
13											
14	ELEVATION CHANGE = $\frac{4-2}{2 \times 6} \times 4 =$				-0.7						
15											
16	ADJUSTED QE =				307.3 OR 307						
17											
18	SUBTRACT SITE				-(+6)						
19											
20	ADJUSTED ELEVATION =				301						
21											
22											
23											
24											

DA FORM 6-12

REPLACES DA FORM 6-12, 1 APR 57, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 OCT 68 UNLESS SOONER EXHAUSTED.

Figure 86. Record of precision registration, fuze quick.

g. Comment 6. During fire for effect, the deflection (3197) is not changed until a positive FDC deflection sensing is obtained. The FDC deflection sensing of RIGHT from round 6 is compared to that obtained from round 2. Since no deflection bracket exists, the deflection is changed by S/2 in the direction opposite the last sensing obtained, to deflection 3199. Round 7 results in an FDC deflection sensing of LEFT. At this point, the registration has resulted in FDC deflection sensing of RIGHT at deflection 3197 and LEFT at deflection 3199. The correct deflection is 3198 (a 2-mil deflection bracket is split).

297.1 Target Hits

a. Occasionally the Forward Observer may enter fire for effect as the result of a target hit. In this case there is no requirement to establish the fork bracket since the target hit yields both an OVER and a SHORT FDC range sensing. The round which hit the target becomes the first round in fire for effect. Positive FDC range sensings are obtained from two more rounds fired at the same quadrant elevation. Now the possibility arises that no preponderances could exist, (T, —, +). In this case positive FDC range sensings must be obtained from three more rounds fired at the same quadrant elevation (for a total of six at the same quadrant elevation). If, after the two rounds are fired, a preponderance does exist, (T, —, —), the quadrant elevation is changed 1/2 fork opposite the preponderance and positive sensings are obtained from THREE rounds. In either case the elevation change is then computed and applied to the mean quadrant elevation to determine the adjusted quadrant elevation.

Note. Regardless of the number of target hits obtained, the normal procedure requires that sensings from six rounds be used in computing the elevation change.

b. The following examples are alternate possibilities for the registration begun in paragraph 297.

Example (1)

Rd No.	DF fired	Chart range	QE fired	Obs corr.	FDC Rg	Sensing DF
1	3215	5090	319	R50-200		
2	3189	4930	306	T	— +	Corr
3			306	— L	—	
4			306	— R	+	
5			308	+ R	+	
6			308	? R	—	
7			308	+ R	—	

Preponderance = 1 OVER

MEAN QE = 307.0

E1 Change = -0.3

Adjusted QE = 307 (307.0 + (-0.3) = 306.7)

Example (2)

Rd No.	DF fired	Chart range	QE fired	Obs corr.	FDC Rg	Sensing DF
1	3215	5090	319	R50-200		
2	3189	4930	306	T	— +	Corr
3			306	— L	—	
4			306	+ R	—	
5			306	? R	+	
6			306	— LN	+	
7			306	— R	+	

Preponderance is 1 SHORT

Mean QE = 306.0

E1 Change = +0.3

Adjusted QE = 306 (306.0 + (+0.3) = 306.3)

c. If a target hit is obtained while a fork bracket is being established, the procedure to follow is the same as in *a* above.

d. If a target hit occurs after the fork bracket has been established, apply the rules from paragraph 295. Compute the elevation change using sensings from six rounds.

297.2 PE, is 38 Meters or Greater

a. The precision registration procedures apply in general to all artillery, regardless of caliber. Exceptions to these procedures occur when the value of the PE_r is equal to or greater than 38 meters.

b. When the value of the PE_r is equal to or greater than 38 meters, round fired as a

result of ADD (DROP) 50, FEE, may be wasted because of the large range probable error. In such cases, the observer should be notified at the start of the mission to request fire for effect when a 200-meter bracket is split.

298. Time Registration, General

If the time of flight were affected by non-standard conditions at the same rate as is range and all time fuzes were made exactly alike, the fuze setting listed in the firing table corresponding to the adjusted elevation would be the adjusted time. If a number of rounds were fired with that fuze setting and with the adjusted quadrant elevation and deflection to the registration point, a zero height of burst would result. A zero height of burst is obtained when a number of rounds fired with the same fuze setting and quadrant elevation results in a mean height of burst at ground level. Because time fuzes are affected by storage conditions and manufacturer's tolerances and time of flight at a different rate than range to non-standard weather conditions, a time registration must be conducted to determine a fuze setting that will produce a zero height of burst for rounds fired with the adjusted quadrant elevation. This fuze setting is termed the adjusted time.

299. Time Registration Procedures

a. The time registration is conducted after the adjusted quadrant elevation has been determined by using fuze quick. During the time registration, all rounds are fired with the adjusted quadrant elevation. If the correct deflection has not been determined prior to the determination of the adjusted quadrant elevation, the observer will sense the range and deviation of all graze bursts and the adjustment of deflection will continue during the time registration. (A precise FDC deflection sensing from an airburst is virtually impossible.) If the correct deflection has been determined before the start of the time registration, the observer will sense only fuze action, AIR or GRAZE.

b. The registering piece is ordered to fire fuze time. The fuze setting for the initial round is normally the fuze setting listed in the firing

table corresponding to the adjusted elevation. However, if an experience fuze correction is known, the initial round may be fired with a fuze setting corresponding to the adjusted elevation plus the experience fuze correction.

c. After the observer's first sensing, the fuze setting is changed 0.4 in an attempt to have the next round burst in the opposite sense. If the sensing is AIR, the fuze setting is too short, and 0.4 is added to the fuze setting. If the sensing is GRAZE, the fuze setting is too great and 0.4 must be subtracted from the fuze setting. This procedure (changing fuze setting 0.4) is continued until a round in the opposite sense is obtained. A 0.4 time bracket is thus established.

d. If the observer reports a height of burst in excess of 50 meters prior to the establishment of a 0.4 time bracket, a change in fuze setting larger than 0.4 may be appropriate.

e. After a 0.4 time bracket is obtained, the bracket is split. The fuze setting determined by splitting the 0.4 time bracket is the trial time. Three rounds are fired at the trial time.

f. After the observer senses the three rounds fired at the trial time, the preponderance of the sensings is determined. The fuze setting is changed 0.2 opposite the preponderance and two rounds are fired. This procedure (adding or subtracting 0.2 from the trial time) will always result in firing at the fuze setting which established the limit of the 0.4 time bracket opposite to the preponderance at the trial time.

g. After the observer senses the two rounds fired at the fuze setting 0.2 away from the trial time, the adjusted time may be computed. The adjusted time is not a true time but is a term applied to a fuze setting. Henceforth, all fuze settings will be referred to as time; i.e., trial time, mean time, etc. The six rounds considered in the computation of the adjusted time are the three rounds fired at the trial time, the last two rounds fired, and the round fired with the same time as the last two rounds that established one end of the 0.4 time bracket. The formula for the computation of the adjusted time is—

$$\frac{\text{Adjusted time} = \text{mean time fired} \pm \frac{\text{Difference in number of airs \& grazes}}{2 \times \text{number of rounds considered}}}{\text{In the above formula the value of—}} \times 0.4$$

$$\frac{\text{Difference in number of airs \& grazes}}{2 \times \text{number of rounds considered}} \times 0.4$$

when expressed to the nearest 0.1 will always be 0.1 unless the preponderance is zero. If the preponderance is AIR, the adjusted time is the mean time plus 0.1. If the preponderance is GRAZE, the adjusted time is the mean time minus 0.1. If there is no preponderance (equal number of AIR and GRAZE) the adjusted time is the mean time.

300. Example of Time Registration

The following is an example of a time registration using a 155-mm howitzer (M109), charge 5 green bag, adjusted elevation 320, adjusted quadrant elevation 324. The fuze setting corresponding to elevation 320 is 22.2.

Round No.	Deflection fired	Time fired	QE fired	Observer sensing
12	2811	22.2	324	A (AIR)
13		22.6	324	A
14		23.0	324	G (GRAZE)
15	BP③	22.8	324	A
16				G
17				A
18	BP②	23.0	324	G
19				G

Comments: Initial round is AIR; 0.4 is added to the time until a time bracket is established (GRAZE at 23.0; AIR at 22.6). The bracket is split and three rounds are fired at 22.8, resulting in two airs, and one graze—a preponderance of air. The time is increased 0.2 and two more rounds are fired at 23.0 (the time which established the graze end of the time bracket). The six rounds in fire for effect are the three rounds fired at 22.8 and the three rounds fired at 23.0. The preponderance of the six rounds is graze; 0.1 is subtracted from the mean time, 22.9, to arrive at the adjusted time of 22.8.

301. Abbreviated Procedure for Time Registration

The following procedure is one that may be

used when speed or ammunition economy takes precedence over accuracy, when only will-adjust missions are to be fired, or when subsequent registrations are to be fired in the same position with the same fuze ammunition lot combinations. The procedure is appropriate when experienced personnel are firing under comparatively stable conditions and are able to judge the reliability of results. The technique is termed "the abbreviated procedure."

a. The trial time is determined as prescribed in paragraph 299a through e.

b. Two rounds are fired at the trial time.

c. If the two rounds fired at the trial time result in mixed sensings, the trial time is the adjusted time.

d. If the two rounds fired at the trial time result in the same sensing, the time is changed 0.2 in the appropriate direction (to the end of the 0.4 time bracket that was sensed opposite to the two rounds fired at the trial time) and one round is fired.

e. If the one round fired at the appropriate end of the time bracket is sensed opposite to the rounds fired at the trial time, the adjusted time is the mean time.

f. If the one round fired at the appropriate end of the time bracket is in the same sense as the rounds fired at the trial time, the registration may be invalid. See paragraph 307 for procedures to determine validity of the time registration when using the abbreviated procedure.

g. Examples of the abbreviated procedure for time registration are given in (1) and (2) below.

(1) Example 1

Round No.	Time	Sensing	Comment
1	19.6	A	Add 0.4
2	20.0	G	Split the 0.4 time bracket
3, 4	19.8	A, G	Trial time (19.8) is the adjusted time

(2) Example 2:

Round No.	Time	Sensing	Comment
1	19.6	G	Subtract 0.4
2	19.2	A	Split the 0.4 time bracket
3, 4	19.4	G, G	Subtract 0.2
5	19.2	A	Adjusted time is 19.3

Section III. VALIDITY OF REGISTRATIONS

302. General

a. An invalid registration may result from—

- (1) A missensing by the observer, causing a false bracket in range, deflection, or fuze setting.
- (2) Errors at the piece.
- (3) Errors at the fire direction center.

b. Whenever a registration does not meet the requirements for validity, it must be continued until valid.

303. Invalid Impact Registration
(Rescinded)

304. Verifying an Impact Registration

a. A registration which results in a single round of one sensing such as five overs, one short; five shorts, one over; one target, five overs or shorts, is normally considered valid. But if the S3 suspects that the one minority sensing is due to an error, he will verify the registration.

b. The procedure for verifying an impact registration is as follows:

- (1) Move 1/2 fork in the appropriate direction (add if the preponderance is short; drop if the preponderance is over) from the last quadrant elevation fired and fire one verifying round.
- (2) If the verifying round results in an FDC range sensing opposite to the preponderance, the registration is considered valid. The verifying round is not considered in computing the adjusted quadrant elevation.
- (3) If the verifying round is in the same sense as the preponderance, fire two more rounds at the same quadrant elevation used to fire the verifying round. If either of these two rounds is in the minority sense, the adjusted elevation is computed from the last six rounds which yield FDC range sensings. If both of these rounds are in the same sense as the preponderance, the registration is invalid and a new fork bracket must be established and another fire for effect conducted.

c. Examples of verifying an impact registration are given in (1), (2), and (3) below.

(1) Example 1.

Rd No.	QE	FDC Rg Sensing	Comment
1	339	+	Fork=7, Move even fork, 8
2	331	—	Split bracket, fire ③
3,4,5	335	+,+,+	All +, Drop ½ F, fire ②
6,7	331	+,+	5 and 1, S3 decides to verify
8	327	—	Reg. is valid, Adj. QE is 331

(2) Example 2.

Rd No.	QE	FDC Rg Sensing	Comment
1	339	+	F=7, Drop even fork
2	331	—	Split bracket, fire ③
3,4,5	335	+,+,+	All +, drop ½ fork, fire ②
6,7	331	+,+	5 and 1, S3 decides to verify
8	327	+	Fire ②
9,10	327	+,—	Valid, compute with rounds fired at QE 327 and 331. Adj. QE is 328

(3) Example 3.

Rd No.	QE	FDC Rg Sensing	Comment
1	339	+	F=7 drop even fork
2	331	—	Split bracket, fire ③
3,4,5	335	+,+,+	All +, drop ½ fork, fire ②
6,7	331	+,+	5 and 1, S3 decides to verify.
8	327	+	Fire ②
9,10	327	+,+	Registration is invalid, Drop even fork.
11	319	—	Split bracket, fire ③
12-14	323	+,—,+	DROP ½ F, fire ②
15,16	319	—,—	Valid Registration Adj QE is 322

305. Valid Time Registration

a. A time registration is considered valid if any of the following combinations of sensings are obtained in fire for effect.

- (1) Three AIR and three GRAZE.
- (2) Four AIR and two GRAZE.
- (3) Two AIR and four GRAZE.

b. If the sensings in fire for effect of a registration are five AIR and one GRAZE, the S3 must request the observer to report the mean height of the airbursts. If the observer reports

a mean height of burst of 15 meters or less, the registration is valid. If the mean height of burst is greater than 15 meters, the registration must be verified.

306. Verification of Time Registration

a. A time registration which results in the following combinations of sensing must be verified:

- (1) Five GRAZE and one AIR.
- (2) One GRAZE and five AIR (mean height of airbursts are greater than 15 meters).

b. The procedure for verification of a time registration is as follows:

- (1) Change the time by 0.2 from the last time fired, adding if the preponderance is AIR; subtracting if the preponderance is GRAZE. Fire one verifying round.
- (2) If the verifying round is in the sense opposite to the preponderance, the registration is valid.
- (3) If the verifying round is in the same sense as the preponderance, two more rounds are fired with the same time as the verifying round. If either of these rounds is in the sense opposite to the preponderance, the adjusted time is computed from the last three rounds fired and the three rounds fired with a time 0.2 away from the time of the last three rounds. If both of the rounds fired with the same time as the verifying round are sensed the same as the preponderance, the registration is invalid and a new 0.4 time bracket must be established and another fire for effect conducted.

c. Examples of verifying time registration are given in (1), (2), and (3) below.

(1) Example 1.

Round	Time	Sensing	Comment
1	14.1	A	
2	14.5	G	0.4 time bracket is established.
3,4,5	14.3	G,G,G	
6,7	14.1	G,G	Five G and 1 A must be verified; subtract 0.2.
8	13.9	A	Registration is valid. Adjusted time is 14.1.

(2) Example 2.

Round	Time	Sensing	Comment
1	14.1	A	
2	14.5	G	
3,4,5	14.3	G,G,G	
6,7	14.1	G,G	Five G and one A must be verified.
8	13.9	G	Verifying round in same sense as preponderance. Fire two more rounds at 13.9.
9,10	13.9	G,A	Compute adjusted time based on rounds 1, 6, 7, 8, 9, and 10. Adjusted time is 13.9.

(3) Example 3.

Round	Time	Sensing	Comment
1	14.1	A	
2	14.5	G	
3,4,5	14.3	G,G,G	
6,7	14.1	G,G	Five G and one A must be verified.
8	13.9	G	
9,10	13.9	G,G	Registration is invalid. Reestablish 0.4 time bracket.
11	13.5	A	0.4 time bracket is established. Enter fire for effect.
12,13,14	13.7	A,G,G	Preponderance is GRAZE.
15,16	13.5	A,A	Four A and two G. Adjusted time is 13.7.

307. Verifying Abbreviated Time Registration

a. If the two rounds fired at the trial time and the subsequent round fired at the end of the bracket are all AIR and the mean height of burst is 15 meters or less, the registration is valid.

b. If these same three rounds are all GRAZE, or all AIR with a mean height of burst greater than 15 meters, the registration may be invalid. In this situation, the apparent adjusted time is the time that established the end of the 0.4 time bracket at which the last round was fired.

c. To verify the apparent adjusted time, the time is changed 0.2 in the appropriate direction (add if last round is AIR; subtract if last round is GRAZE) and one verifying round is fired.

d. If the verifying round is in the sense opposite the last three rounds fired, the apparent adjusted time is considered verified.

e. If the verifying round is in the same sense as the last three rounds fired, one more round is fired at the same time as the verifying round. If this round is in the sense opposite to the preceding round, the adjusted time is the mean of the apparent adjusted time and the time at which the last two rounds were fired. If this last round fired is still in the same sense as the four preceding rounds, a new 0.4 time bracket must be established and a new fire for effect conducted.

f. Examples of the abbreviated procedure for invalid time registration are given in (1) and (2) below.

(1) *Example 1.*

Round	Time	Sensing	Comment
1-----	22.4	A	Add 0.4.
2-----	22.8	G	Split the 0.4 time bracket.

Round	Time	Sensing	Comment
3,4 ----	22.6	G,G	Subtract 0.2.
5-----	22.4	G	Apparent adjusted time is 22.4. Must be verified.
6-----	22.2	A	Apparent adjusted time is considered verified. Adjusted time is 22.4.

(2) *Example 2.*

Round	Time	Sensing	Comment
1-----	21.8	G	Subtract 0.4.
2-----	21.4	A	Split the 0.4 time bracket.
3,4 ----	21.6	A,A	Add 0.2.
5-----	21.8	A	Mean height of burst reported to be 25 meters. Apparent adjusted time is 21.8. Must be verified.
6-----	22.0	A	Fire another round.
7-----	22.0	G	Adjusted time is 21.9 (A, G at 21.8 and A, G at 22.0). If round number 7 had been AIR, a new registration would have been required.

Section IV. CENTER-OF-IMPACT AND HIGH-BURST REGISTRATIONS

308. General

a. The opportunities to conduct precision registrations are limited since the procedures require visual adjustment on a clearly defined, accurately located registration point in the target area. At night, the adjustment of fire on a registration point without some type of illumination is impossible. In desert, jungle, or arctic operations, clearly defined registration points normally are not available. To overcome these limitations, either of two alternate registration procedures may be used. These procedures are known as the center of impact (CI) registration and the high-burst (HB) registration. In a CI or HB registration, the mean burst location of a group of rounds (normally six) fired with a single set of data is determined.

b. A HB registration offers distinct advantages over a CI registration in that a time fuze is employed. Since airbursts are used, deflection, range, and fuze corrections may be determined simultaneously; it is easier to observe, especially at night; and corrections may be ob-

tained for areas concealed from ground observation.

309. Advantages (Rescinded)

310. Disadvantages (Rescinded)

311. Selection of Point at Which To Register

a. The point at which a center-of-impact registration is to be fired should be—

- (1) Close to the center of the zone into which the unit is expected to fire.
- (2) In a relatively level area, free of ravines and objects which might obscure the bursts.
- (3) In an area visible to the observers.

b. The point at which a high-burst registration is to be fired should be—

- (1) Over the center of the zone into which the unit is expected to fire.
- (2) High enough to be visible to the observers.

- (3) High enough that airbursts are assured (consideration must be given to height of burst probable error) but not so high that the angle of site at the gun exceeds 50 mils. Fifty meters above the ground is usually a good height of burst.

312. Orientation of the Observers

a. Lines of known direction for the observers should be established on the ground. The observers must be furnished azimuths and vertical angles to the expected point of burst. The azimuths are usually determined graphically from the firing chart. The vertical angles are normally computed using the C and D scales of the GST.

b. A message to the observers prior to firing a CI or HB registration contains a warning order, orientation data for each OP, a directive to observer 01 to measure and report vertical angles, and a directive to both observers to report when ready to observe. Since 01 is the control OP and is more accurately located than 02, vertical angles should be measured at 01.

Example: OBSERVE HIGH BURST. 01, AZIMUTH 1065, VERTICAL ANGLE + 10, MEASURE THE VERTICAL ANGLE. 02, AZIMUTH 785, VERTICAL ANGLE + 8. REPORT WHEN READY TO OBSERVE.

c. Observer procedures are discussed in paragraphs 224 and 225.

313. Determination for Firing Data

a. The point at which the registration is to be fired is plotted on the firing charts. The HCO determines and announces the chart range and deflection to the selected point.

b. The VCO determines the site to the selected point. The vertical interval used in the determination of site for a high-burst registration is determined by subtracting the altitude of the gun from the sum of the altitude of the ground under the selected point and the desired height of burst above the ground.

c. The computer determines the fire commands based on the announced chart data. The

method of fire is BASE PIECE (number so-and-so) ONE ROUND, AT MY COMMAND. In well trained units, the methods of fire may be changed to BASE PIECE (so many) ROUNDS AT (so many) SECONDS INTERVAL after the observers have oriented on the initial round. When the method of fire is BASE PIECE (so many) ROUNDS AT (so many) SECONDS INTERVAL, each observer must carefully identify the round to which each reading pertains.

d. Firing data is not changed during the registration unless a change is necessary to move the burst to a point visible to the observers or to increase site if graze bursts occur in a high-burst registration. All rounds considered in a CI or HB must have been fired with the same data.

314. Procedure During Firing of High-Burst or Center-of-Impact Registration

a. When the battery has reported READY and the observers have reported READY TO OBSERVE, the S3 commands FIRE. The first round is used to orient the observers and is not normally considered as one of the usable rounds.

b. If either of the observers could not observe the initial round firing data may be changed and the burst moved until both observers have picked up the burst.

c. After the observers have located the burst, the registration is continued. One round at a time is fired until six usable rounds have been obtained. Each observer reports the azimuth to each burst, and the designated observer reports the vertical angle to each burst.

d. Any round which appears to be erratic is disregarded. In judging whether a round is erratic, the S3 must consider the location of the observers with respect to the gun-target line and the size of the probable errors. Any round not disregarded as erratic or missensed by an observer is considered usable.

315. Determination of the Location of Center-of-Impact or High-Burst

a. When six usable rounds have been fired, the azimuths from each OP and the vertical

angles are averaged. The average azimuth reported by each observer is the azimuth from the OP to the mean burst location of the six usable rounds. The average vertical angle is the vertical angle to the mean burst location.

b. The following information is known and is used to determine the location of the CI or HB. Location of OP's length of base (distance between OP's), direction from one OP to the other, azimuth from each OP to center-of-impact or high-burst, vertical angle from one OP to center-of-impact or high-burst.

c. The methods by which the CI or HB may be located in order of accuracy are—

- (1) Computation of coordinates and altitude of center-of-impact or high-burst (FM 6-2).
- (2) Computation of azimuth, distance, and vertical interval from one OP to center-of-impact or high-burst and then polar plotting from that OP.
- (3) Graphic intersection and computation of vertical interval from one OP to center-of-impact or high-burst.

316. Determination of Chart Data to Center-of-Impact and High-Burst

a. After the center-of-impact or high-burst is located and plotted, the HCO measures the deflection and range to the center-of-impact or high-burst from the battery which fired the mission. The range and deflection measured are the chart range and chart deflection.

b. After the center-of-impact or high-burst is located and plotted, the VCO determines site to the center-of-impact or high-burst in the following manner:

- (1) Determine the vertical interval by subtracting the altitude of the battery from the altitude of the center-of-impact or high-burst.
- (2) Divide the vertical interval by the chart range (GST) for the appropriate charge.

317. Determination of Adjusted Elevation

The quadrant elevation used to fire the six

usable rounds in a center-of-impact or high-burst registration is the adjusted quadrant elevation. To determine the adjusted elevation, the site (para 316b) is subtracted from the adjusted (fired) quadrant elevation.

318. Example Problem

a. A 155-mm howitzer battalion (M109) has just made a night occupation of position. Survey has been completed. In order to fire accurately a predawn preparation, the S3 decided to fire a high-burst registration (charge 5 GB). After studying the map, the S3 decides to fire the high-burst at grid intersection 6242 with a desired height of burst above ground of 60 meters. The altitude at the grid intersection is 407 meters.

b. The survey officer furnished the following data:

Coordinates of	5708538148,	altitude 381 meters.
Battery B		
Coordinates of 01	6159939123,	altitude 436 meters.
Coordinates of 02	6039639620,	altitude 431 meters.
Distance 01 to 02	1,302 meters	
Azimuth 01 to 02	5,199 mils	

c. The HCO constructed a firing chart with 01, 02, and all batteries plotted. He measures the following azimuths and distances from 01 and 02 to the 6242 grid intersection:

- (1) 01 to 6242 — azimuth 141 mils, distance 2900 meters.
- (2) 02 to 6242 — azimuth 604 mils, distance 2870 meters.

d. The VCO computes the vertical angles from 01 and 02 to the desired location of the high-burst.

- (1) Desired altitude of HB is 467 meters (407 + 60).
- (2) 01 — vertical interval = + 31 (467 — 436). — vertical angle = + 31/2,900 = + 11 mils (GST).
- (3) 02 — vertical interval = + 36 (467 — 431). — vertical angle = + 36/2,870 = + 13 mils (GST).

e. The following message is sent to the observers:

OBSERVE HIGH BURST.

01, AZIMUTH 141, VERTICAL ANGLE
+ 11, MEASURE THE VERTICLE
ANGLE.

02, AZIMUTH 604, VERTICAL ANGLE
+ 13.

REPORT WHEN READY TO OBSERVE.

f. The HCO measures and announces the following chart data for Battery B: RANGE 6240, DEFLECTION 2377.

g. The VCO computes and announces the site:

(1) Vertical interval = +86 (467 — 381).

(2) Site = +86/6240 (GST, charge 5 GB)
= +15 mils.

h. The computer determines and sends to the battery the following fire command:

BASE PIECE ADJUST, SHELL HE, LOT
ZT, CHARGE 5. FUZE TIME, BASE
PIECE ONE ROUND, AT MY COM-
MAND, DEFLECTION 2377, TIME 21.6,
QUADRANT 327.

i. When the base piece and both observers report ready, firing is begun. As each round is observed, the observers report in numerical order; e.g., 01, AZIMUTH (so much), VERTICAL ANGLE (so much); 02, AZIMUTH (so much). The azimuths and vertical angles are recorded, and the next round is fired. When six usable rounds have been observed, the mission is ended. The following data was reported by 01 and 02 and recorded and averaged at FDC:

Round No.	01 azimuth	01 vertical	02 azimuth
1* -----	---	---	---
2 -----	110	+8	590
3 -----	108	+8	588
4 -----	111	+7	589
5 -----	115	+7	588
6* -----	---	---	---
7 -----	107	+7	590
8 -----	111	+7	590
Total -----	662	+44	3535
Average -----	110	+7	589

*Note. Rounds number 1 and 6 were considered erratic and were disregarded.

j. The location of the mean burst is then computed in the following manner (fig. 87):

(1) Compute distance from 01 to high burst.

Apex angle = 479 mils (589 — 110).

Angle at 02 = 1,410 mils (1,999 — 589).

Using law of sines: $\frac{01-HB}{\sin 1,410} = \frac{1,302}{\sin 479}$

log 1,302	=	3. 114611
+ log sin 1,410	=	9. 992400
		13. 107011
— log sin 479	=	9. 656209
log distance 01 to HB	=	3. 450802
Distance 01 to HB	=	2,823.6 meters.

(2) Compute coordinates and altitude of high-burst location.

dE = D sin B	
log D	= 3.450802
log sin 110	= 9.032548
log dE	= 2.483350
dE = +304	
01 = 61599	
61903	
dN = D cos B	
log D	= 3.450802
log cos 110	= 9.997462
log dN	= 3.448264
dN = +2807	
39123	
41930	
dH = D tan vertical angle	
log D	= 3.450802
log tan 7	= 7.837105
log dH	= 1.287907
dh = +19	
436	
455	

Coordinates of high burst are 619034
—1930; altitude is 455.

k. The chart operators plot the high-burst location and determine the following chart data:

(1) HCO: Range 6,130 meters; deflection 2378.

(2) VCO: Vertical interval = +74 (455—381)

Site = + 74/6130 (GST, charge 5 GB) = + 13.

l. The following is a tabulation of the essential information derived from this registration:

Chart date	Adjusted (fired) data
Range -----	6130 meters QE 327 mils
Deflection -----	2378 mils El 314 (327—(+13))
Site -----	+ 13 mils Deflection 2377 mils
	Time 21.6

HIGH BURST (CENTER OF IMPACT) REGISTRATION (FM 6-40)											
COMPUTATION OF HB (CI) LOCATION											
Date Fired		Chg 5GB		Dt 2377		FS 21.6		OE 327			
Observer Readings				Interior Angles							
Rd	O1		O2		O1 on Left			O1 on Right			
Nr	Az	VA	Az								
1	96	10	572	Az O1-O2			Az O1-HB (CI)				
2	110	18	590	+6400 if necessary			+6400 if necessary				
3	108	18	588	Total			Total				
4	111	17	589	-Az O1-HB (CI)			-Az O1-O2				
5	115	17	588	Σ O1			Σ O1				
6	95	19	590	Az O2-HB (CI)			Az O2-O1				
7	107	17	590	+6400 if necessary			+6400 if necessary				
8	111	17	590	Total			Total				
9				-Az O2-O1			-Az O2-HB (CI)				
10				Σ O2			Σ O2				
662 144 3535				Total							
110 17 589				Average							
				Apex Angle		Bearing = 6400-Az		Bearing = Az		Az O1-HB-Bearing	
				Σ O1		dE-dN		dE-dN		110	
				+Σ O2		dE-dN		dE-dN			
				Sum		3200		Bearing			
						dE-dN		dE-dN		Bearing	
				-Sum		Bearing = Az-3200		Bearing = 3200-Az		N 110 E	
				Apex Angle		479					
Distance O1 HB (CI)											
Log base O1-O2				3 114 611		Log conversion factor, meters to yards add 0.038863					
+Log sin Σ O1 O2				9 992 400							
Sum				13 107 011							
-Log sin Apex Angle				9 656 209							
diff = Log dist O1-HB (CI)				3 450 802		*Determine the distance O1-HB (CI) to check computations of dE, dN & dH by polar plotting from O1 on average azimuth and computed dist.					
Dist O1-HB (CI) ²				2823.6 M							
Log of dE, dN, and dH											
Log dist O1-HB (CI)				3 450 802		Log dist O1-HB (CI)					
Log sin Bearing				9 032 548		Log cos Bearing					
Sum =				2 483 350		Sum =					
Log dE				2 483 350		Log dN					
Coordinates of O1				E 61 599		N 39 123		H 436			
-dE				304		-dN		2807			
Location of HB (CI)				E 61 903		N 41 930		H 455			
COMPUTATION OF GFT SETTING											
Alt HB (CI)				455		OE fired					
-Alt Btry				381		-Site VI/HB (CI) Rg					
VI				74		Adj Elev					
				314		Chart data to HB (CI) location					
						Deflection 2372 of Range 4130 M					
						GFT "A" Charge 5 Lot 27					
						Range 6130 Elevation 314 Time 21.6					
						(HB or CI Rg) (Ti fired)					
						R1					

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Figure 87. Computation of high-burst registration.

Section V. REGISTRATION WITH MORE THAN ONE AMMUNITION LOT

319. General

The ballistic characteristics of ammunition vary from one lot to another. Corrections for certain variables (i.e., weight of projectile) can be computed. Corrections for other variables can only be determined by registration with each lot. Only when a large quantity of ammunition from a particular lot is present should a registration be made with that lot. The procedures described in this section apply when more than one large quantity lot is on hand.

320. Procedure for Precision Registration With More Than One Lot

a. As soon as the adjusted quadrant elevation has been determined for the first lot, the registration is begun with the second lot. The observer should be notified, and he continues to sense as in fire for effect.

b. The first round of the new lot is fired with the adjusted quadrant elevation of the first lot. As soon as a positive FDC range sensing is obtained, the quadrant elevation is changed 1 fork in the appropriate direction. (If the value of the fork is an odd number, the quadrant elevation is changed by the next higher even

value. This procedure facilitates splitting the bracket, when established. The true value of the fork is used to compute the adjusted elevation.) This procedure is continued until a fork bracket is established. The fork bracket is split. Procedures in paragraphs 295 and 296 are followed as in the registration with the first lot of ammunition.

c. The correct deflection established for one lot is used for all lots because there is no appreciable effect on deflection due to the ballistic difference between lots. Therefore, if the correct deflection has not been established for the first lot by the time the adjusted elevation is determined, the registration with the second lot is begun and the deflection adjustment is continued during the second registration until the correct deflection is established.

d. The use of different fuze lots with the same propellant and projectile lots does not require separate impact registrations.

e. When one lot of time fuzes is to be used with more than one propellant or projectile lot, the fuze correction determined for that fuze lot by registration with one projectile-propellant combination is normally valid for use with the other propellant and projectile lots.

CHAPTER 19

DETERMINATION AND APPLICATION OF REGISTRATION CORRECTIONS

Section I. INTRODUCTION

321. General

a. The purpose of a registration is to determine corrections for the cumulative effect of nonstandard weather, materiel and ammunition, and of chart and survey errors. The corrections determined from a registration are highly accurate for a small area around the registration point during a short period of time immediately following the registration. Registration corrections are considered to have acceptable accuracy anywhere within an area bounded by transfer limits (par. 322).

b. This chapter deals with practical methods of determining and applying registration corrections.

322. Transfer Limits

Registration corrections are valid within the following transfer limits (fig. 88):

a. When the chart range to the registration point is 10,000 meters or less, transfer limits are—

- (1) *Range*—1,500 meters beyond and short of the registration point.
- (2) *Direction*—400 mils right and left of the battery-registration point line.

b. When the chart range to the registration point is more than 10,000 meters, transfer limits are—

- (1) *Range*—2,000 meters beyond and short of the registration point.
- (2) *Direction*—4,000 meters right and left of the battery-registration point line.

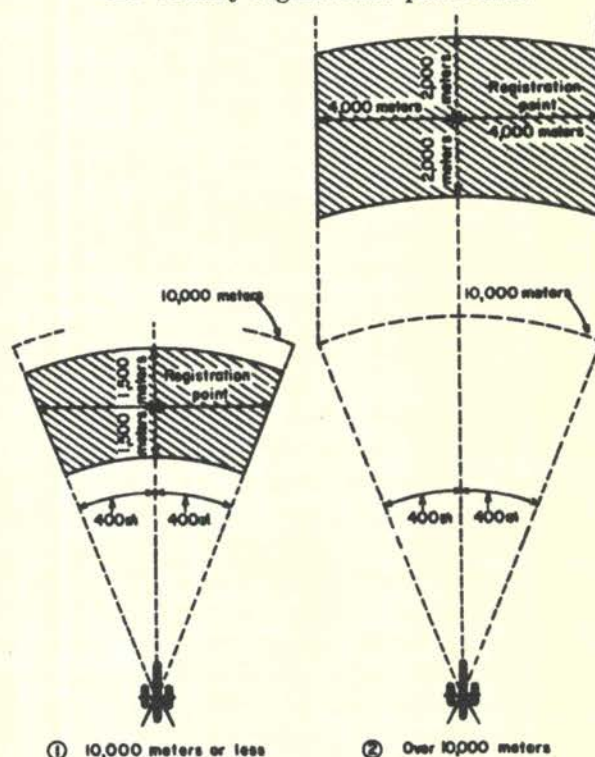


Figure 88. Transfer limits.

Section II. REGISTRATION RANGE CORRECTION

323. Computation of Range Correction

a. If standard conditions exist, the elevation to be fired to achieve the chart range is the elevation listed in the firing table for that range. When nonstandard conditions exist, the range achieved by firing a particular elevation differs from the range indicated in the firing table by an amount equal to the cumulative effect of all nonstandard conditions. A registration determines the elevation required to achieve the chart range (adjusted elevation). The adjusted elevation

is the sum of the elevation listed in the firing table for chart range and the elevation correction necessary to compensate for the cumulative effect of all nonstandard conditions. The range correction is the correction in meters corresponding to the elevation correction.

b. The range correction is determined in the following manner:

- (1) Determine, from the firing table, the range corresponding to adjusted elevation.

- (2) Subtract the chart range from the range corresponding to the adjusted elevation. The result is the range correction.

Example: A 155-mm howitzer battery has registered with charge 5. The chart range to the registration point is 5,930 meters. The adjusted elevation is 314. The base piece is over battery center.

324. Determination and Application of Range K

a. The range K is an expression of the range correction as a ratio of meters correction to thousands of meters in range. The range K is determined by dividing the range correction by the chart range (modified by base piece displacement) in thousands of meters (to the nearest 100 meters).

b. Continuing the example in paragraph 323b, the range K is determined as follows:

$$\text{Range K} = +219/5.9 = +37.1 \text{ or } +37 \text{ meters per } 1,000 \text{ meters.}$$

c. Within transfer limits, the range correction is assumed to vary directly with chart range. To determine the range correction to be applied for a target within transfer limits, the range K is multiplied by the chart range to the target in thousands of meters (to the nearest 100 meters).

d. To determine the elevation to be fired, the range correction, determined as prescribed in c above, is added to the chart range and the elevation corresponding to the sum is determined from the firing table.

e. Continuing the example from b above, it is desired to fire at a target at a chart range of 7,100 meters.

$$\begin{array}{rcl} \text{Range correction} & = & +37 \times 7.1 = +263 \\ \text{Chart range} & = & 7,100 \\ \hline & & 7,360 \text{ meters} \end{array}$$

Elevation corresponding to range 7,360 = 405 mils.

325. Fuze Correction

a. The fuze correction is determined by subtracting the fuze setting listed in the firing table corresponding to the adjusted elevation (or elevation plus the complementary angle of site) from the adjusted time.

Example: A registration by a 155-mm howitzer firing charge 5 has been completed. The ad-

justed QE is 324, and the adjusted time is 22.0 seconds. The angle of site is +5.3 mils.

Adjusted elevation plus comp site
(Adjusted QE minus angle of site)

$$(324 - (+5.3)) \text{ ----- } 318.7 \text{ mils}$$

Fuze setting corresponding to

$$318.7 \text{ mils ----- } 21.7 \text{ seconds}$$

$$\text{Fuze correction } (22.0 - 21.7) \text{ ----- } +0.3 \text{ seconds}$$

b. Within transfer limits the fuze correction is considered a constant and is applied to the fuze setting listed in the firing tables corresponding to the elevation plus comp site to the target.

326. GFT Setting

a. Registration range and fuze corrections are usually portrayed graphically in the form of a GFT setting. The elements of a GFT setting are always expressed and recorded in the following sequence:

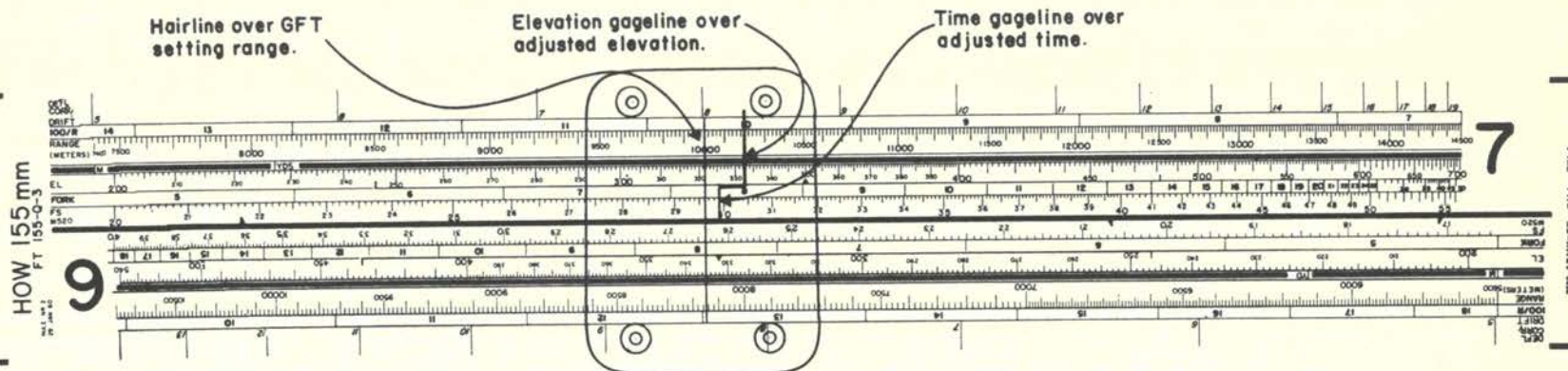
- (1) Unit that registered.
- (2) Charge.
- (3) Ammunition lot.
- (4) Chart range (modified by base piece displacement to the nearest 100 meters).
- (5) Adjusted elevation.
- (6) Adjusted time (if applicable).

Example: GFT B, Charge 7, Lot X. Range 10,000, Elevation 332, Time 29.9.

b. The GFT setting is placed on the GFT in the following manner (fig. 89):

- (1) Place hairline on the cursor over the chart range (modified by base piece displacement).
- (2) Draw a fine line on the cursor, parallel to the hairline, over the adjusted elevation. This elevation gage line should extend from the drift scale halfway through the fork scale.
- (3) Draw another fine line on the cursor, parallel to the hairline, over the adjusted time. This time gage line extends from the fuze setting scale upward halfway through the fork scale.
- (4) Draw a fine horizontal line, in the fork scale, connecting the ends of the elevation and time gage lines.

c. To determine data to any target within transfer limits of the registration point, the



GFT "B", Ch 7, Lot —, rg 10,000, el 332, Ti 29.9

Figure 89. Elevation and time gagelines on GFT.

hairline is placed over the chart range. 100/R is read under the hairline. Elevation, fork, and drift are read under the elevation gageline. Fuze setting is read under the time gageline.

327. GFT Setting on the GFT Fan

a. To establish a GFT setting on the GFT fan, the fan vertex is placed against the registering battery pin and the cursor vertex against a needle in the registration point. Then, using a straightedge, a fine line (elevation gageline) is drawn on the cursor from the cursor vertex through the adjusted elevation to the right edge of the ballistic scale (fig. 90).

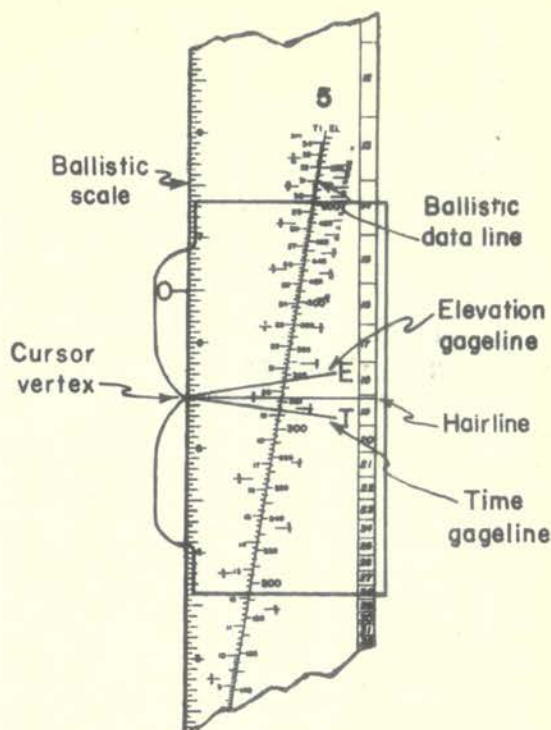
b. If a time registration has been made, a time gageline is drawn in a similar manner from the cursor vertex through the adjusted time to the right edge of the scale.

c. The elevation and the fuze setting for a given target are read under the elevation and time gagelines, respectively, when the fan vertex is against the pin in the battery position and the cursor vertex is against the needle in the target.

d. Fork and drift are considered functions of elevation and are read opposite the elevation appearing under the elevation gageline.

e. In some cases, all of the ballistic data for a particular charge cannot be plotted on the ballistic scale in one continuous line. This is because of the limited width of the scale. In such cases, the ballistic data line is divided into two segments. These segments are constructed to provide a substantial overlap in data between segments (fig. 90). An elevation or time gageline constructed for use with one of the segments cannot be used with the other segment because the triangles formed would not be similar and corrections applied would not be proportional.

f. If, after a registration, the adjusted elevation falls within the overlap, two elevation gagelines are drawn from the cursor vertex. These are drawn so that one gageline passes through the adjusted elevation on each segment of the ballistic data line. This is done when the GFT fan is positioned with the vertex of the fan against the pin in the position of the registering battery and the cursor vertex against a needle in the registration point.



GFT A: Chg 5, lot —, rg 5,480, el 335, ti 19.2

Figure 90. Elevation and time gagelines of GFT fan cursor.

g. If the adjusted elevation does not appear in the overlap but transfer limits include part of both of the segments of the ballistic data line, an elevation gageline is constructed and used in the normal manner for that segment of the ballistic data line on which the adjusted elevation appears (1, fig. 91).

h. To construct an elevation gageline for the other segment, move the cursor along the ballistic scale until the elevation gageline already constructed falls across both segments of the ballistic data line. Note the elevation appearing under the elevation gageline on the segment for which it was constructed. Draw another elevation gageline from the cursor vertex through that same elevation on the other segment (2, fig. 91). The gageline for the second segment should intersect the ballistic scale of the second segment only to avoid confusing the two gagelines when working in the region of the lower segment. This second elevation gageline is used, within transfer limits of the registration point, for reading the elevation on the second segment

(3, fig. 91). If a time registration has been made, a similar procedure is followed to construct time gagelines as necessary.

328. Selection of GFT Setting

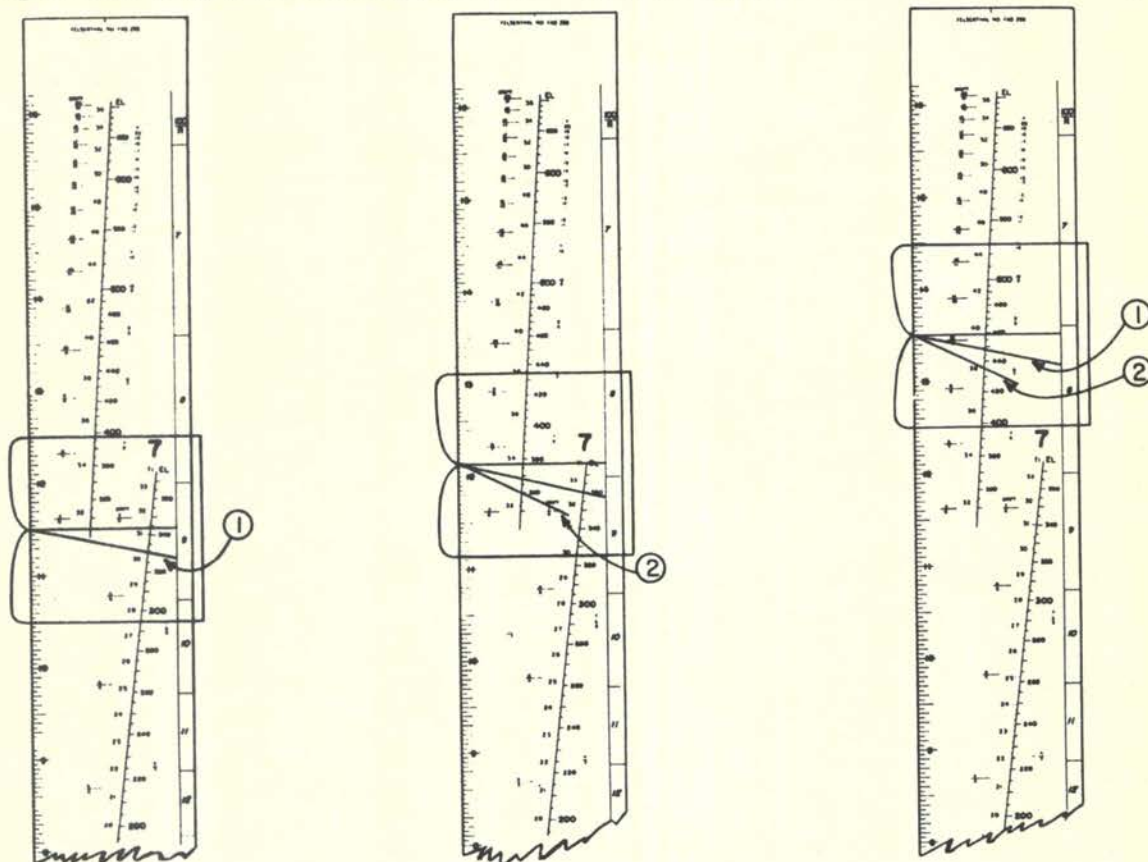
a. When only one battery of a battalion has registered, the GFT setting of this battery will be used by the nonregistering batteries of the same caliber. (A variation from this rule if calibration velocity errors (VE's) are known is explained in par. 378.) If the batteries are widely separated in range or direction of fire to the registration point, the common GFT setting will not be accurate for the nonregistering batteries. However, in the absence of other data, this registration data is the best available. It

is desirable, therefore, that the center battery be chosen to register unless the center battery is greatly echeloned in range from the flank batteries. In this case, the registering battery should be the battery nearest the mean range to the registration point.

b. If all batteries have registered with the same charge and this charge is to be used in a mission, each computer uses the GFT setting established by the registration of his battery.

329. Correction for Base Piece Displacement—Range

A GFT setting derived from a registration is an expression of the range achieved by firing with the adjusted elevation. The chart range is



① El gageline drawn for first segment of ballistic data line at rg 11,500, el 330.

② Cursor is moved up to overlap first el gageline reads 360. Second el gageline is drawn through 360 on second segment.

③ Second el gageline is used to read elevations beyond the first segment of the ballistic data line.

Figure 91. Constructing elevation gagelines for a two-segment ballistic data line.

measured from the battery center to the registration point, center-of-impact, or high-burst. If the registering piece is in front of or behind the battery center, the measured chart range is not the range achieved. Therefore, the GFT setting range should be the chart range modified by the amount the base piece is in front of or behind the battery center.

Example: A 105-mm howitzer battery has registered with charge 5. Chart range is 5,000 meters. The adjusted elevation is 335. The executive officer's report indicates that the base piece is 30 meters behind the battery center (fig. 92). The range actually achieved is 5,030 meters ($5,000 + 30$). The GFT setting is GFT A: charge 5, lot Y, range 5,030 elevation 335.

330. GFT Settings for More Than One Lot

a. If the same charge has been used for registration with more than one lot of ammunition, two GFT settings may be placed on the cursor. The gagelines may be marked with the lot designation or color coded according to lot. Additional GFT settings are always recorded but are placed on the cursor only when used.

b. When the GFT fan is used, different cursors are usually used for each GFT setting. The lot and charge used are written on the cursor. All or several GFT settings may be placed on a single cursor, but the gagelines must be color coded or otherwise marked for identification.

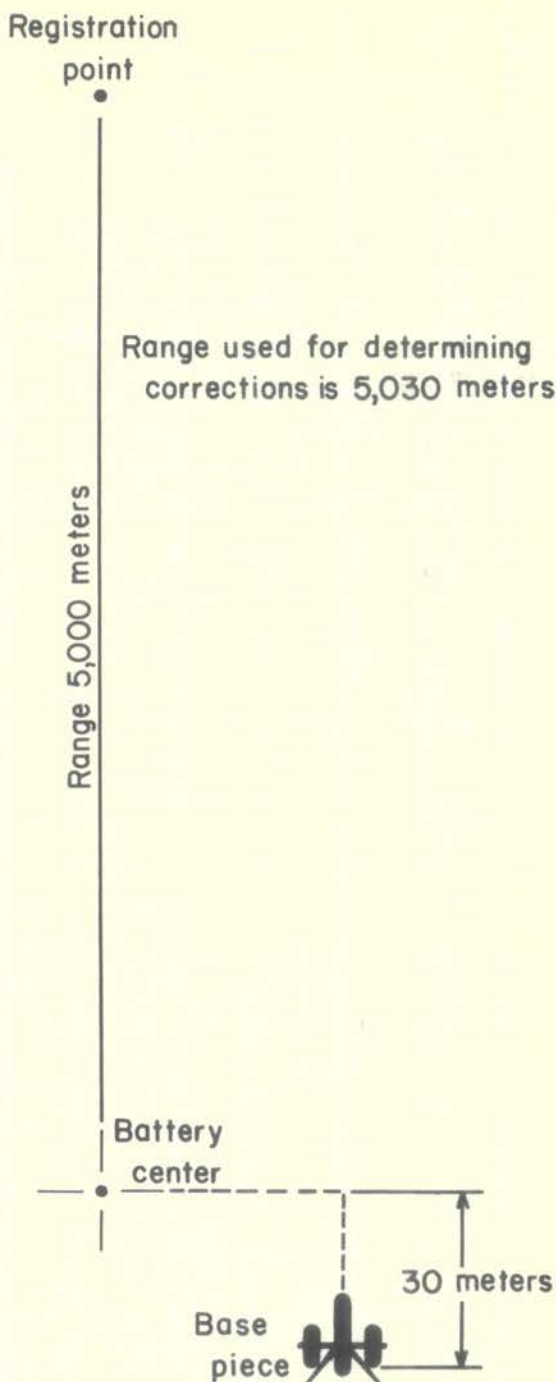


Figure 92. Base piece displacement correction—range.

Section III. REGISTRATION DEFLECTION CORRECTION

331. Adjusted Deflection

The correct deflection derived from a precision registration or the fired deflection in a center-of-impact or high-burst registration is the adjusted deflection only if the base piece is not displaced right or left from the battery center. If the base piece is displaced laterally from the battery center, the correct deflection must be modified to what the correct deflection would have been if the base piece had been over the battery center. The amount of the correction to be applied to the correct deflection is determined by dividing the amount of the lateral displacement in meters by the chart range in thousands of meters (to the nearest 100 meters). If the base piece is to the right (left) of the battery center, the displacement correction is to the right (left).

Example: Battery A has registered on the registration point. The correct deflection determined was 2,652 mils. Chart range is 5,100 meters. The executive officer reports that the base piece is 40 meters to the right of the battery center (fig. 93). The correction for base piece displacement is right 8 mils ($40/5.1$). The adjusted deflection is 2,644 mils ($2,652 + R\ 8$).

332. Deflection Correction

a. The deflection correction is the correction that must be applied to the chart deflection to a target in order to determine a deflection that will hit the target. The adjusted deflection determined from a registration is the deflection which placed the mean burst center of rounds from all pieces in the battery at the registration point or the center-of-impact or high-burst location. To determine the deflection correction for the registration point (center-of-impact or high-burst location), the chart deflection is subtracted from the adjusted deflection. If the adjusted deflection is greater (less) than the chart deflection, the correction is left (right). For example, a registration has been completed on registration point 1. The adjusted deflection is 2,632. The chart deflection to registration point 1 is measured as 2,640 mils. The deflec-

tion correction for registration point 1 is right 8 ($2,632 - 2,640 = R\ 8$).

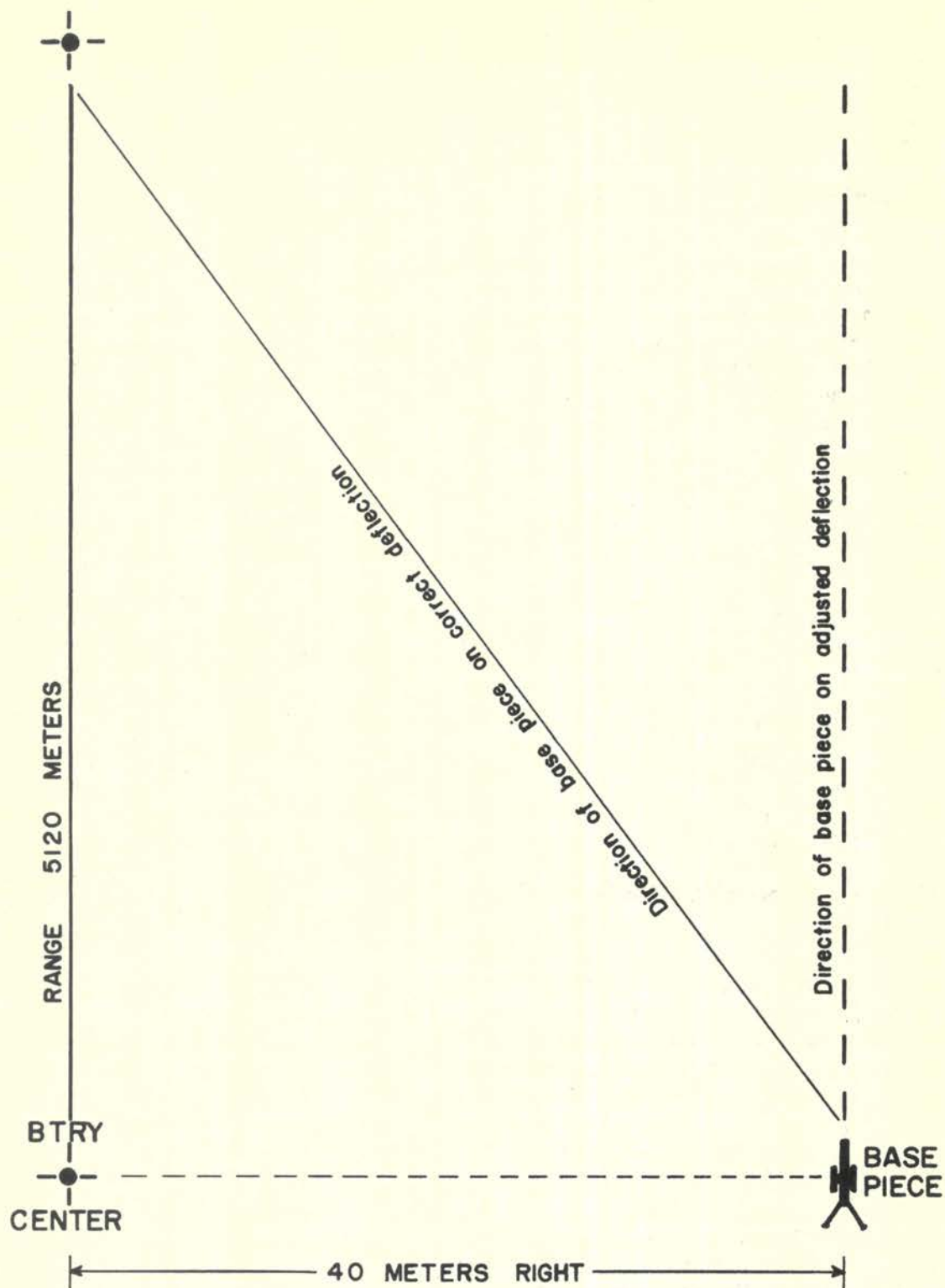
b. After the initial registration, the temporary deflection index is erased and the deflection index is constructed corresponding to the adjusted deflection. This procedure causes the chart deflection and the adjusted deflection to be the same, and the deflection correction corresponding to the adjusted elevation becomes zero. After subsequent registrations, a new deflection index is not constructed.

333. Construction of the Deflection Index

a. After the initial registration, a deflection index corresponding to the adjusted deflection is constructed. The procedure for constructing the index is as follows:

- (1) Place the vertex of the range-deflection protractor at the battery and the arm against the needle in the registration point (or plotted location of the center-of-impact or high-burst).
- (2) Place a needle in the chart opposite the adjusted deflection on the arc.
- (3) With the vertex at the battery, place the arm against the needle placed in (2) above.
- (4) With a 6H pencil, draw the index extending from the needle, approximately 1 inch toward the battery and approximately 1 inch away from the battery.
- (5) Draw an arrowhead on the index pointing toward the battery at a point one-eighth inch beyond the needle. Mark the battery designation at the upper end of the index. The appropriate battery color is used to make the arrowhead and the letter designation of the battery.

b. The right (left) supplementary index is located by placing the leftmost (rightmost) graduation on the arc of the range-deflection protractor over the deflection index and placing a needle opposite the rightmost (leftmost) graduation. The index is drawn as described



Displacement correction for deflection = $\frac{40 \text{ METERS RIGHT}}{5.1} = \text{Right 8 mils}$

Figure 93. Base piece displacement correction—deflection.

in a(3) through (5) above. The part of the supplementary index beyond the arrowhead is then accentuated with a colored pencil—red for the right supplementary index and blue for the left supplementary index.

334. Deflection Correction Scale

a. To determine the deflection correction for an elevation other than the adjusted elevation, differences in drift must be considered. As the elevation is increased, the projectile will drift farther to the right; therefore, a left correction (the difference between the drift which will occur at the adjusted elevation and the drift which will occur at the elevation to be fired) must be applied. As the elevation is decreased, the projectile will not drift as far to the right; therefore, a right correction must be applied. For convenience, a deflection correction scale, from which the deflection correction for any elevation within transfer limits may be taken by inspection, is constructed.

b. When only one battery has registered, the deflection correction scale that is used by all batteries of the same caliber is based on the GFT setting of the registering battery.

c. When all batteries have registered, separate deflection correction scales are constructed for each battery. Each battery uses its own deflection correction scale.

335. Construction of the Deflection Correction Scale

a. The deflection correction scale is constructed by the computer after the elevation gageline has been drawn on the cursor of the GFT. For example, the following data has been determined for an 8-inch howitzer: (FT 8-J-3).

Chart data	Adjusted data
Deflection 2,600	Charge 4, lot XT
Range 5,700	Deflection 2,608
	Elevation 304

b. The GFT setting is drawn on the GFT (GFT A: Charge 4, lot XT, range 5,700, elevation 304). This is the initial registration. The deflection index is constructed at deflection 2,608, and the deflection correction corresponding to the adjusted elevation becomes zero.

c. On a card or piece of paper, draw a line. The midpoint on this line represents the adjusted elevation and is labeled with the adjusted elevation. The end points of the line represent the range transfer limits. Determine the elevation corresponding to each transfer limit (4200 and 7200) and label the end points of the basic scale (1, fig. 94).

d. Determine the elevations at which drift changes within transfer limits. Place the hairline over each drift change line and read the elevation under the hairline. Record those elevations on the deflection correction scale (2, fig. 94).

e. Place the deflection correction corresponding to the adjusted elevation directly below the adjusted elevation. Since drift increases as elevation increases, the deflection corrections will increase in increments of 1 mil to the left at each greater elevation where drift changes. Conversely, as elevation decreases, deflection corrections will increase in increments of 1 mil to the right. Record the deflection corrections on the scale as indicated in 3, figure 94.

f. The computer may place the deflection correction scale on the GFT. With the GFT setting drawn on the cursor, the hairline is placed over the chart range to the registration point. The deflection correction corresponding to the adjusted elevation is then written in pencil in the drift block through which the elevation gageline passes. Each succeeding drift block to the right (range increasing) has a

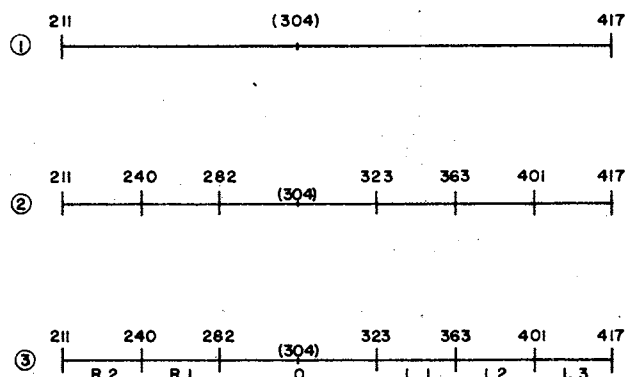


Figure 94. Deflection correction scale.

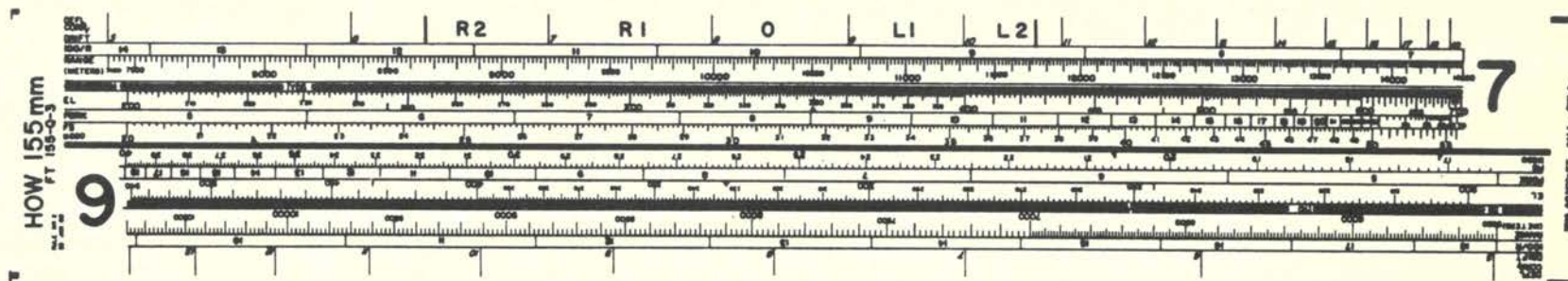


Figure 95. GFT with deflection correction scale.

deflection correction 1 mil more to the left than the block to its left. Each succeeding drift block to the left (range decreasing) has a deflection correction 1 mil more to the right than the block to its right (fig. 95). Transfer limits are shown by lines on the drift scale opposite the *elevations* corresponding to the upper and lower transfer limits. To determine the deflection correction at any range within transfer limits, the computer places the hairline over the chart range and reads the deflection correction in the drift block through which the elevation gageline passes.

336. Deflection Correction Scale—GFT Fan

a. The deflection correction scale is constructed by the chart operator after the elevation gageline has been drawn on the cursor. For example, the following GFT setting has been determined for a 155-mm howitzer battery: Charge 5, lot X, range 6,000 elevation 315: The adjusted deflection was 2,621.

b. Since this is the initial registration, the temporary deflection index is erased, and the deflection index is constructed at deflection 2,621. The deflection correction corresponding to the adjusted elevation becomes zero. The GFT setting is placed on the cursor of the GFT fan as described in paragraph 327.

c. The upper and lower transfer limits are determined to be 7,500 and 4,500 respectively. By placing the hairline over range 7,500 the elevation gageline intersects the elevation scale at elevation 435. A short line is constructed with a grease pencil opposite elevation 435 per-

pendicular to the long axis of the scale. This is upper limit of the deflection correction scale. The cursor is moved down the scale until the hairline is over range 4,500 and the elevation gageline intersects the elevation scale at elevation 219. The lower limit of the deflection correction scale is indicated by constructing a short line perpendicular to the long axis of the scale opposite elevation 219. Now, by using a pencil, the drift change lines within the transfer limits (8/7, 7/6, 6/5, 5/4, and 4/3) are extended to intersect the elevation scale. A deflection correction of zero is entered between the drift change lines (6/5 and 5/4) that bracket elevation 315. Between drift change lines (7/6) and (6/5), a deflection correction of left 1 (L1) is entered. Between drift change lines (8/7) and (7/6), the deflection correction is left 2 (L2). For the remaining upper part of the scale (in this case drift change line (8/7) to upper transfer limit), the correction is left 3. L3 is entered between the two lines drawn on the ballistic scale. The lower half of the scale is completed in the same manner, except that the deflection correction is to the right.

d. If another registration is conducted with the same charge for another sector of fire, the corrections determined from this registration are entered on the ballistic scale in the same manner as described in a through c above, but a different colored pencil is used for ease in recognition. A new deflection index is not constructed. The computer must combine the deflection and deflection correction and announce the total.

CHAPTER 20

METEOROLOGICAL CORRECTIONS AND VELOCITY ERROR

Section I. THE MET MESSAGE

337. General

Among the conditions that affect a projectile after it leaves the tube is the state of the atmosphere through which the projectile passes. The three properties of the atmosphere that United States Artillery considers in its gunnery computations are wind (direction and speed), air temperature, and air density. The meteorological (met) message is a coded message that contains information about current atmospheric conditions.

338. Types of Met Messages

Two types of met messages are provided for artillery fire. Type 2 message is used by air defense artillery cannon. Type 3 message is used for artillery cannons and free rockets firing at surface targets and is the type with which field artillery is primarily concerned.

339. Contents of the NATO Met Message

The North Atlantic Treaty Organization (NATO) met message is divided into an introduction and body (fig. 96).

a. The introduction to the NATO met message consists of four 6-character groups and one 3-letter group.

- (1) *Group 1.* The first three letters (MET) of group 1 designate the transmission as a met message. The next letter indicates whether the message is for surface (S) or air defense (A) fire. The next number is the type of met message (2 or 3). The last number is the designation of the octant of the earth in which the met station is located. The key to the octant designation code is as follows:

Code No.	Octant
0	North latitude, 0° to 90° West
1	North latitude, 90° West to 180°
2	North latitude, 180° to 90° East

Code No.	Octant
3	North latitude, 90° East to 0°
4	Not used
5	South latitude, 0° to 90° West
6	South latitude, 90° West to 180°
7	South latitude, 180° to 90° East
8	South latitude, 90° East to 0°
9	Used when latitude and longitude are not given in group 2

- (2) *Group 2.* Group 2 designates the center of the area in which the met message is valid. This may be expressed either in degrees and tens of minutes of latitude and longitude or by the indicator (in the clear or in code) of the meteorological unit which produced the met message.
- (3) *Group 3.* The first two digits of group 3 represent the day of the month on which the message becomes valid. The next two digits indicate the hour at which the met message becomes valid (in the U.S. message the time the sounding began). The last two digits indicate the hour at which the met message ceases to be valid. The hours refer to Greenwich Civil Time.
- (4) *Group 4.* The first three digits of group 4 indicate the altitude of the met station meteorological datum plane (MDP) above mean sea level in tens of meters. The next three digits indicate the atmospheric pressure at the meteorological datum plane (MDP), corrected to mean sea level, expressed as a percentage (to the nearest 0.1 percent) of the standard pressure at mean sea level.
- (5) *Group 5.* The first two letters of group 5 designate the originating nation of the met station. The last letter indicates the service to which the met sta-

tion belongs. The code used in group 5 is as follows:

Country	Code
Belgium	BE
Canada	CA
Denmark	DA
France	FR
German Federal Republic	GE
Greece	GR
Iceland	IC
Italy	IT
Luxembourg	LU
Netherlands	NL
Norway	NO
Portugal	PO
Turkey	TU
United Kingdom	UK
United States	US
<i>Service</i>	
Land forces	L
Air forces	A
Naval forces	N

b. The body of the met message consists of a number of lines (up to 16), each line consisting of two 6-number groups each. Each line contains ballistic weather data for a particular altitude zone. Ballistic data are weighted averages of the conditions that exist from the surface up through the altitude zone indicated by the number.

- (1) The first two digits of each line are the line number. The line number identifies a NATO altitude zone. The lines are

numbered in sequence from 00 (surface conditions) to 15 (18,000 meters altitude).

- (2) The next two digits indicate the direction from which the ballistic wind is blowing expressed in hundreds of mils *true* azimuth.
- (3) The next two digits represent the speed of the ballistic wind expressed in knots.
- (4) The first three digits of the second group of six numbers indicate the ballistic air temperature expressed as a percentage (to the nearest 0.1 percent) of International Civil Aviation Organization (ICAO) standard. Standard air temperature is 59° F. (15° C. or 288.16° Kelvin). A 1-percent change in standard temperature is equivalent to a 5.1869° F. change in temperature.
- (5) The last three digits indicate the ballistic air density expressed as a percentage (to the nearest 0.1 percent) of ICAO standard density.

340. Selection of Met Message Line

One of the keys to the proper solution of the met message is the selection of the proper line of the message. The proper line is that for the altitude closest to the summit of the trajectory. The met message line number can be obtained from the appropriate firing tables.

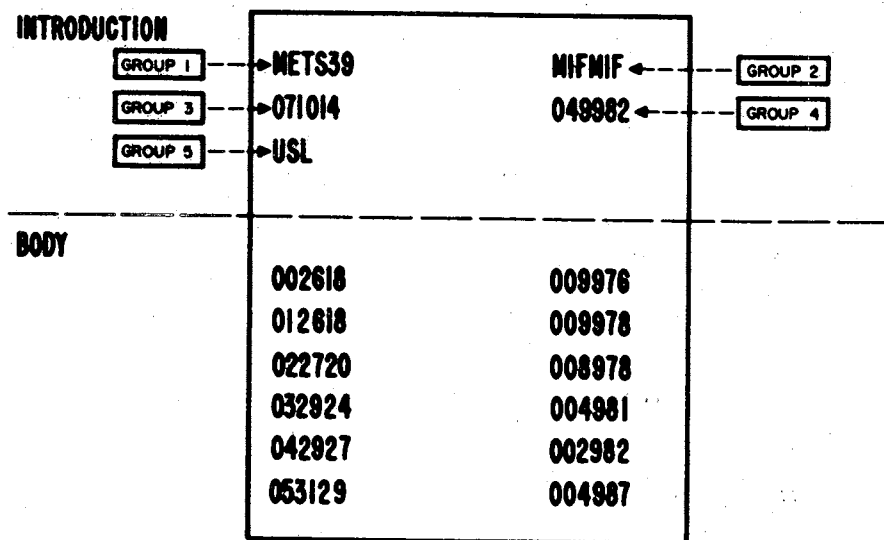


Figure 96. The NATO met message.

a. As the maximum ordinate (height of the summit of the trajectory above the gun) is a function of quadrant elevation and muzzle velocity (charge), the proper line number can be determined by entering the "Line Number of Meteorological Message" table, for the appropriate charge, with the adjusted quadrant elevation for the point for which the met message is to be solved. The value determined is rounded to the nearest whole number. If the

value determined falls at a multiple of 0.5, it is rounded to the next higher whole number.

b. If a met message is being solved prior to firing, no adjusted quadrant elevation is known, and the line number is determined by entering the "Complementary Range, Line Number" table, for the appropriate charge, at the chart range and height of target above the gun, both the nearest 100 meters.

Section II. VELOCITY ERROR

341. General

a. The best way to determine corrections is by registration. Corrections determined from a registration compensate for the combined effect of all nonstandard conditions which existed at the time of the registration. A portion of the registration corrections compensates for nonstandard conditions which can be measured at the time that the registration is being fired. The nonstandard conditions which can be determined are—

- (1) Ballistic wind (from met message).
- (2) Ballistic air temperature (from met message).
- (3) Ballistic air density (from met message).
- (4) Weight of projectile (from firing battery).
- (5) Drift (from firing tables).
- (6) Propellant temperature (measured at gun position).
- (7) Rotation (from firing table).

b. Corrections for the nonstandard conditions listed in *a* above can be computed by using the firing tables.

c. There are ballistic variations from firing table standards which cannot be measured (wear of tube, moisture content of the propellant, shell surface finish, etc.). Corrections for these unknown variations are included in the corrections determined from a registration. For convenience, the total of the unknown variations are grouped together as one variation, termed "velocity error" (VE). The variations which compose velocity error are classified into the following groups:

- (1) Factors effecting the developed muzzle velocity.
- (2) Factors affecting the ballistic coefficient of the projectile.
- (3) Small errors in survey, charts, FDC equipment, and fire control instruments.

d. Velocity errors are assumed to be a measure of weapon and ammunition performance and are not considered subject to change in weather and other measurable nonstandard conditions. Velocity error may be expressed as feet per second (f/s) or meters per second (m/s). The computed VE should be treated as an unchanging constant, until evidence from firing indicates it should be changed.

342. Determination of Velocity Error

The determination of velocity error (VE) requires that the observations upon which the met message is based be concurrent with a registration. The determination of VE is accomplished by the following steps:

a. Determine the total range correction (para. 344).

b. Compute the met range correction. For convenience, correction for nonstandard projectile weight and rotation of the earth together with corrections for ballistic range wind, air temperature, and air density are considered met range corrections.

c. Determine the ΔV range correction. The symbol ΔV is used to represent the total variation from standard muzzle velocity. In the present context, ΔV is the sum of VE and the correction to muzzle velocity for propellant

temperature. ΔV range correction is determined by subtracting the met range correction from the total range correction.

d. Convert the ΔV range correction to ΔV in feet per second (meters per second).

e. Determine VE (para. 347).

343. Entry Range

It is necessary to determine the range at which to determine unit correction (*entry range*). The entry range is the sum of the chart range to the point for which the met message is being solved and the complementary range. Complementary (comp) range is the range correction corresponding to the complementary angle of site and is determined from the tabular firing table. To determine comp range, enter "Complementary Range, Line Number" table with the chart range to the nearest 100 meters and the height of target above gun to the nearest meter. Interpolation for height of target above gun may be necessary.

Example: 155-mm howitzer, charge 5; chart range, 7,020 meters; altitude of battery, 237 meters; altitude of target, 500 meters.

Height of target above gun, +263 meters

Enter table at range 7,000 and height of target above gun +263

	Height of target above gun		
	+200	+263	+300
7,000	55	73.9	85

Complementary range is 74 meters. Entry range is 7,094 (7,020 + 74).

344. Determination of Total Range Correction

a. The total range correction from a registration is computed by subtracting the entry range from the range corresponding to the adjusted elevation plus comp site.

Example: 155-mm howitzer battery has completed a registration using charge 7. Chart range to registration point is 9,940 meters; altitude of battery, 286 meters; altitude of registration point, 573 meters; adjusted QE, 358 mils.

Vertical interval (573-286)	-----	+287 meters
Angle of site (+287/9940; C and D scales GST).		+29.4 mils
Adjusted elevation plus comp site (Adjusted QE minus angle of site).		328.6 mils
Range corresponding to adjusted elevation plus comp site.		10,127 meters
Comp range	-----	+38 meters
Entry range (9940+38)	-----	9,978 meters
Total range correction (10,127-9,978).		

b. The total range correction may also be computed in the manner described in paragraph 323.

345. Computation of Met Corrections

Met range and deflection corrections are computed concurrently. Firing table data are based on an assumed standard trajectory which exists under prescribed standard conditions of weather and materiel. If the variation between an existing condition and the assumed standard condition are measured, a correction for that variation can be determined by multiplying the variation by a correction for each unit of variation. Unit corrections are contained in the firing tables. To aid in computing met corrections, the Met Data Correction Sheet is used. An example of the solution of a met message and the use of the Met Data Correction Sheet (fig. 97) is shown below.

Example: Assume that a 155-mm howitzer battery has registered and the following information is available:

FDC Data: GFT B: Charge 7, lot XY, range 9,910, el 326; adjusted quadrant elevation 334; azimuth to registration point 1420; altitude of battery, 250 meters; altitude of registration point, 319 meters; latitude 34° N; grid convergence, +3 mils. Battery executive officer reports; Weight of projectile, 1 square; powder temperature 54° F. Met message as shown in figure 96.

a. Enter all known data in the proper spaces on the form; i.e., charge, adjusted quadrant elevation, chart range to nearest 10 meters, altitude of battery, height of target above gun, latitude to nearest 10°, direction of fire to the nearest 100 mils, propellant temperature, weight of projectile.

b. Enter data from introduction to met message.

c. Determine proper met message line number (para. 340). Enter data from proper line on form.

d. Determine complementary range. Enter complementary range and add it to chart range to determine the entry range (para. 343).

e. Since grid convergence never exceeds 45 mils and the ballistic wind is measured to the nearest 100 mils, the true azimuth is considered to be the grid azimuth and requires no conversion.

f. Compute chart direction of wind by subtracting the direction of fire from the direction of the wind (e above). Enter the "Wind Components" table with chart direction of wind and determine components of a 1-knot wind. Enter components.

g. Compute the range wind and cross wind (to the nearest knot) and enter it in the appropriate spaces.

h. Determine difference in altitude between the meteorological datum plane (MDP) and the battery (Δh). Enter the "Temperature and Density Corrections" table with Δh (to the nearest 10 meters) to determine corrections to air temperature and density. Apply corrections and enter corrected temperatures and density in appropriate blocks. (New firing tables will contain a table D, labeled Corrections to temperature (ΔT) and Pressure (ΔP) in Percent to compensate for the difference in meters between the height of Battery and MDP. When this table is available the metro message will be solved using air temperature-air pressure values and air density will be disregarded.

i. Enter the "Propellant Temperature" table with powder temperature to determine the correction to muzzle velocity (to the nearest foot/second). Enter muzzle velocity correction (to be used later in determination of VE).

j. Compute variations from standard for range wind, temperature, density, and projectile weight.

k. Enter the "Ground Data" table at entry range (d above) rounded to nearest 100 meters to determine—

- (1) Drift correction.
- (2) Cross wind unit correction.
- (3) Range wind unit correction.
- (4) Air temperature unit correction.
- (5) Air density unit correction.
- (6) Projectile weight unit correction.

l. Determine rotation corrections to range and azimuth and enter them. "Rotation" tables are entered at entry range to nearest listed range, azimuth of fire to the nearest listed value, and latitude to the nearest 10°

m. Compute cross wind correction and then add rotation correction for azimuth, drift cor-

rection, and cross wind correction to determine the met deflection correction.

n. Multiply variations from standard by unit corrections and enter results under column headed PLUS or MINUS whichever is appropriate. The sign of each range correction is the same as the sign of the corresponding unit correction.

o. Add values in each column. Find the difference between the two columns (Plus and Minus) and round off to the nearest meter; the result is the met range correction.

346. Determination of ΔV

a. The ΔV range correction is determined by subtracting the met range correction (para. 345) from the total range correction (para. 344).

b. To determine ΔV in feet per second, (meters per second), the ΔV range correction is divided by the muzzle velocity unit correction (Ground Data Table). The sign of the ΔV range correction is always opposite to the sign of the ΔV . If the ΔV range correction is *plus* the unit correction is extracted from the *Decrease* column. If the ΔV range correction is *minus* the unit correction is extracted from the *Increase* column.

347. Computation of Velocity Error

The VE in feet per second (f/s) (meters per second (m/s)) is computed by subtracting the correction to muzzle velocity (MV) for propellant temperature (PT) (para. 345 from ΔV (para. 346.)).

348. Average Velocity Error

a. A velocity error (VE) is computed whenever a registration and met message are concurrent. Among the errors corrected by the VE range correction are minor met message errors. Contrary to the other factors included in VE, the met message errors may vary from message to message and are unpredictable. To smooth out the met errors, each new VE determined in the same position as previous VE's is averaged with the old VE. The old VE may be a previously determined average VE. This method gives most weight to the most recently determined VE but does not disregard the previous VE's.

MET DATA CORRECTION SHEET									
BATTERY DATA					MET MESSAGE				
Charge 7	Adj OE 334	Chart Rg 9910	Latitude 30°N	Type Msg 3	Octant 9	Area/Unit MIF MIF			
Alt of Btry (100 ft)		250		Date 07	Time 10-14	Alt MDP 049		Pressure 98.2	
Alt of MDP		490		Line Nr 03	Wind Dir 29	Wind Speed 24	Air Temp 100.4	Air Density 98.1	
Btry above MDP (Δh)		- 240		Δh Corrections			④	④	
Alt of Target (nearest meter)		319		Corrected Values			101.0	100.5	
Height of burst above target		—							
Alt of burst		319							
Alt of Btry (nearest meter)		250							
Height of Target (burst) above gun (m)		+ 69		Comp Rg + 9	Chart Rg 9910	Entry Rg 9919			
WIND COMPONENTS AND DEFLECTION									
When direction of wind is less than direction fire add		6400							
Dir of Wind		2900							
		2900							
Dir of fire		1400							
Chart Dir of Wind		1500				Rotation Corr ① R 9		Drift Corr L 7.4	
Cross Wind	Wind Speed 24	x Comp ① 99	① 24	Knots x .51	=		Cross Wind Corr ① 12.2		
Range Wind	Wind Speed 24	x Comp ① 10	① 10	Knots x .51	=		Met Defl Corr ① 3.9		
MET RANGE CORRECTIONS									
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus			
Range Wind	① 2	0	① 2	10.4	20.8				
Air Temp	101.0	100%	① 1.0	- 7.6		7.6			
Air Density	100.5	100%	① .5	34.8	17.4				
Proj Weight	10	40	① 3	- 10		30.0			
Rotation	- 36 x 87						31.3		
						38.2	68.9		
							38.2		
							30.7		
COMPUTATION OF VE									
VE		- 25 1/s				Total Range Corrections	+ 177		
Prop Temp 54 °F	Correction to MV for Prop Temp	- (- 7) 1/s				Met Range Correction	- (- 31)		
ΔV		- 32 1/s		MV unit Corr + 6.4	ΔV Range Correction		+ 208		
						Total Range Correction			
Old VE _____ + New VE _____ = _____ ÷ 2 = Ave VE _____ 1/s									
Concentration # A J 187				Battery A		Date/Time 7 Apr 60			

Figure 97. Solution of the met message.

Example:

VE determined at 0800 is — 10 f/s.

VE determined at 1200 is — 12 f/s.

Average VE to be used after 1200 is — 11 f/s.

$$\begin{array}{r} (-12) + (-10) \\ \hline 2 \end{array}$$

VE determined at 1600 is — 15 f/s.

Average VE to be used after 1600 is — 13 f/s.

$$\begin{array}{r} (-11) + (-15) \\ \hline 2 \end{array}$$

b. A velocity error is considered wholly valid only for the position and charge at which it was determined. When a unit has displaced and cannot register immediately, the VE from the last position may be used but transfers may not be accurate. As soon as a VE is determined in the new position, VE's from previous positions are disregarded.

348.1 Computation of Met Fuze Correction

a. The fuze setting corresponding to the adjusted elevation plus complementary angle of site approximates the correct fuze setting. Since fuze setting varies at a slower rate than does elevation, under nonstandard conditions, a more accurate approximation can be obtained by correcting, for nonstandard conditions, the fuze setting corresponding to the adjusted elevation plus complementary angle of site. Fuze Setting Change Tables (Table J) are designed to compensate for the same nonstandard conditions which affect range.

- (1) *Met Fuze Correction.* The met fuze correction is equal to the algebraic sum of the individual fuze setting corrections required to compensate for variations from standard conditions. The met fuze correction for nonstandard conditions is determined by multiplying the unit factors by the corresponding departures from standard. Add separately those changes which increase and those which decrease the fuze setting. Subtract the smaller from the larger sum to find the met fuze correction and express the result to the nearest tenth. The sign of the cor-

rection will be that of the column with the larger sum.

- (2) *Total Fuze Correction.* The total fuze correction is determined by subtracting the fuze setting corresponding to elevation plus complementary angle of site from the adjusted time.

- (3) *Fuze Correction.* The fuze correction is determined by subtracting the met fuze correction from the total fuze correction.

b. Use of the Fuze Setting Change Tables eliminates the error in assuming that the fuze correction is constant. The technique involved is similar to VE determination in that the effect of nonstandard conditions on fuze setting is computed at the time of registration and subtracted from the total fuze correction. When a current met is received, a met fuze correction is computed in much the same manner as is the met range correction. The fuze setting corresponding to the new adjusted elevation is determined and the total fuze correction (met fuze correction plus the fuze correction) is added to this fuze setting to obtain the new adjusted fuze setting.

Example:

A 155-mm howitzer (M109) unit has registered and obtained the following GFT setting. GFT B: chg 6, lot XY, rg 8300, el 357, ti 27.6. The total fuze correction is $27.6 - 28.1 = -0.5$. A concurrent met is solved and the met fuze correction computed -0.6 . This is subtracted from the total fuze correction and the resulting fuze correction ($+0.1$) is filed for future use.

A new met is received and solved resulting in the following GFT setting: GFT B: chg 6, lot XY, rg 8300, el 333. Assume the met fuze correction to be $+0.3$. To this is added the fuze correction determined above ($+0.1$) to obtain the total fuze correction ($+0.4$) to be applied to the fuze setting corresponding to the met corrected elevation. Thus the GFT fuze setting is 28.8. ($26.4 + (+0.4)$).

MET DATA CORRECTION SHEET									
BATTERY DATA				MET MESSAGE					
Charge 7	Adj OE	Chart Rg 10430	Latitude 30° N	Type Msg 3	Octant 9	Area/Unit MIF MIF			
Alt of Btry (10 m)		250		Date 07	Time 14-18	Alt MDP 049		Pressure 980	
Alt of MDP		490		Line Nr 03	Wind Dir 42	Wind Speed 18	Air Temp 101.1	Air Density 96.6	
Btry above MDP (Δh)		-240		Δh Corrections			③ - 0.6	④ - 2.4	
Alt of Target (nearest meter)		335		Corrected Values			101.7	99.0	
Height of burst above target		—							
Alt of burst		335							
Alt of Btry (nearest meter)		250							
Height of Target (burst) above gun (m)		+85		Camp Rg 12	Chart Rg 10430	Entry Rg 10442			
WIND COMPONENTS AND DEFLECTION									
When direction of wind is less than direction fire add		6400							
Dir of Wind		4200							
Dir of fire		1400							
Chart Dir of Wind		2800							
Cross Wind	Wind Speed 18	x Comp ③ .38	④ 7	Knots x .53	Rotation Corr ① R .9				
Range Wind	Wind Speed 18	x Comp ③ .92	④ 17	Knots	Drift Corr L 8.1				
				Cross Wind Corr ③ 3.7					
				Met Defl Corr ① R 53.5					
MET RANGE CORRECTIONS									
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus			
Range Wind	① H 17	0	① H 17	- 9.7			164.9		
Air Temp	101.7	100%	① D 1.7	- 9.3			15.8		
Air Density	99.0	100%	① I 1.0	- 38.1			38.1		
Proj Weight	20	40	① I 2	- 9			18.0		
Rotation	- 36 x .87						31.3		
							268.1		
Met Rg Corr									
COMPUTATION OF VE									
VE		- 20 i/s				Total Range Corrections			
Prop Temp 81 °F	Correction to MV for Prop Temp	+ 5 i/s				Met Range Correction	- 268		
ΔV		- 15 i/s		MV unit Corr + 6.6	ΔV Range Correction		+ 99		
						Total Range Correction	- 169		
Old VE _____ + New VE _____ = _____ ÷ 2 = Ave VE _____ i/s									
Concentration # A5 187		Battery A			Date/Time 7 Apr 60				

Figure 98. Application of velocity error.

Section III. APPLICATION OF MET AND VE CORRECTIONS

349. Application of Velocity Error

a. Frequently, it is undesirable to register each time the weather changes. In order to keep range correction current under such a situation, a technique called met plus VE is used. The major change in corrections is due to changes in met conditions and propellant temperature. A new met message will provide current met corrections, VE is virtually constant. By adding current met range correction to ΔV range corrections determined from the current average VE in feet per second (meters per second) and current corrections to muzzle velocity for propellant temperature, a total range correction is determined. The total range correction thus determined is applied to chart range in the same manner as a range correction determined from a registration. A GFT setting is made by placing the hairline at the chart range and constructing the elevation gageline at the elevation corresponding to the corrected range (chart range plus the total range correction).

b. In converting ΔV in feet per second (meters per second) to a ΔV range correction, the ΔV is multiplied by the muzzle velocity unit correction and the result is always given the sign of the unit correction used. The unit correction is determined at the range used to solve the met message and is taken from the *Decrease* column if the ΔV is minus and the *Increase* column if the ΔV is plus.

Sample problem:

Given 155-mm howitzer, charge 7,
lot VZ.

Chart range to registration 10,430 meters
point.

Altitude of battery	-----	250 meters
Altitude of registration point	-----	335 meters
Azimuth of fire	-----	1,360 mils
Weight of projectile	-----	2 squares
Current powder temperature	-----	81° F
Current average VE	-----	-20 f/s
Latitude	-----	34° N
METS39	MIFMIF	
071418	049980	
USL		
004116	014963	
014015	011964	
024116	011964	
034218	011966	
043917	013966	

Solution (fig. 98).

Met range correction	-----	-268 meters
VE	-----	-20 f/s
Correction to MV for propellant temperature.	-----	+5 f/s
ΔV	-----	-15 f/s
MV unit correction	-----	6.6 meters
ΔV range correction (6.6×15)	-----	+99 meters
Total range correction (-268+99)	-----	-169 meters
Chart range	-----	10,430 meters
Corrected range (10,430+(-169))	-----	10,261 meters
Elevation for range 10,261	-----	336 mils
GFT B: Chg 7, lot VZ, rg 10, 430 el 336		

350. Determination of Range Correction for Targets Outside Transfer Limits

a. The use of the current VE is not restricted to transfer limits of the point at which the VE was determined.

Caution: Corrections determined for targets close to the maximum range of the piece are not reliable.

b. Corrections for targets outside transfer limits can be computed using the *met plus VE technique*. The met corrections are determined using the

chart range, vertical interval, and direction to the target in question. ΔV is converted to a ΔV range correction using the MV unit correction determined at the entry range for the target.

351. Deflection Corrections

a. Corrections for deflection and range are best determined from a registration. As a result of the initial registration, the deflection index is constructed. The construction of the deflection index applies graphically the total amount of the initial registration correction for deflection. This total amount includes the correction for weather, which is subject to frequent changes. A deflection correction scale is constructed. The deflection correction for the registration point range is zero.

b. A change of the deflection correction as determined from a subsequent registration or from a new met message will modify this zero deflection correction. Normally, a new deflection index is not constructed (par. 332). To modify the deflection correction by the correction determined from a met message, it is necessary to know the amount of the registration deflection correction that was due to weather. This requires a met message taken concurrently with the initial registration. If a later met message indicates a weather change, a new deflection correction scale must be constructed. The deflection correction at the chart range will be the algebraic sum of the deflection correction at chart range from the previous deflection correction scale and the deflection correction change that was due to weather.

c. For example, a registration has been conducted and a concurrent met message has been solved for a 155-mm howitzer, using charge 5.

- (1) Corrections from registration and met message.

Chart deflection (df) = 2,400 mils

Adj df (initial registra- = 2,386 mils
tion at 1600 hours)

Df correction determined = Right 14 mils
by registration.

Df index constructed at = 2,386 mils
deflection

Df correction at registra- = 0 mil
tion point range (1600
hours)

Met df correction (1600 = Right 8 mils
hours) (recorded but
not used).

- (2) At 2200 hours new met corrections are computed (no registration).

Met df correction (2200 = Right 10 mils
hours)

(Change in weather
equals new met df cor-
rection minus old met
df correction.)

Change in weather = Right 2 mils
(right 10—right 8).

Df correction for chart = 0 mil
range (1600 hours) (df
correction scale).

Df correction at chart = Right 2 mils
range (2200 hours)
(0 + right 2).

- (3) The next morning at 0600 hours a second registration is conducted and new met corrections are computed (adjusted elevation 265 mils).

Adj df (0600 hours) = 2,391 mils

Chart df = 2,386 mils

Df correction at regis- = Left 5 mils
tration point range
(2,391—2,386).

Met df correction (0600 = Right 1 mil
hours) (recorded but
not used.)

- (4) At 1000 hours new met corrections are computed (no registration).

Met df correction (1000 = Left 2 mils
hours)

Change in weather (left = Left 3 mils
2—right 1).

Df correction for chart = Left 5 mils
range (0600 hours)

DF correction at chart = Left 8 mils
range (1000 hours)
(left 5 + left 3).

(5) At 1400 hours a new met message is computed (no registration).

Met df correction (1400 = Right 3 mils hours)

Change in weather (right = Right 5 mils 3 - left 2).

Df correction for chart = Left 8 mils range (1000 hours)

Df correction at chart = Left 3 mils range (1400 hours) (left 8 + right 5).

d. The data in c above may be tabulated for ready reference as follows:

Registration Data

Time	Chart df	Adjusted df	Reg df corr	Met df corr	Df corr
1600-----	2, 400	*2, 386	R14	R8	0
2200-----				R10	R2
0600-----	2, 386	2, 391	L5	R1	L5
1000-----				L2	L8
1400-----				R3	L3

*Deflection index constructed at deflection 2386 after registration.

352. Deflection Corrections Outside Transfer Limits

a. A deflection correction can be determined for targets outside transfer limits. The current met message is solved for the target and a met deflection correction determined. The met deflection correction for the registration point is compared with the met deflection correction for the target, and the difference is applied to the current deflection correction at the registration point.

Example:

Current deflection correction at registration Right 5 point.

Current met deflection correction at registration point. Right 2

Met deflection correction at target..... Left 1

Difference in met deflection corrections..... Left 3

Deflection correction at target (R5 + L3)----- Right 2

b. A deflection correction scale based on the deflection correction determined can be constructed for use with the met plus VE GFT setting determined in order to use the target as a met check point.

Section IV. EXPERIENCE CORRECTIONS

353. General

In some situations, such as a hasty occupation of position or when restrictions are placed on registration, current registration and met corrections may not be known or obtainable. In such a case, the S3 must decide what corrections, if any, are to be applied to data to improve the accuracy of fires. Except in unusual cases where prior knowledge of the weather, ammunition, and weapon is not available, the S3 will resort to an analysis of experience corrections as a basis for applying corrections. This procedure is followed until met or registration corrections are available.

354. Experience VE Corrections

The latest previously determined VE, or average VE, will be used as the basis for a GFT

setting. It is better to establish a GFT setting with this information than to ignore it until a registration is accomplished.

355. Experience Met (Range) Corrections

If a current met message is not available, the data for a GFT setting may be improved by using corrections for weather, ammunition, and weapons performance experienced from previous met messages and registrations. Estimating corrections based solely on such records should only be done with extreme caution.

356. Average Fuze Correction

Evaluation of all previous time registrations of a specific fuze will invariably indicate that a relatively constant fuze correction is required to obtain the proper height of burst. This fac-

tor is the average fuze correction. The average fuze correction, if applied to the fuze setting for the initial round, should cause the round to burst at approximately the desired height. Similarly, any known fuze correction determined from experience should be applied to the

adjusted time prior to determining the range for construction of a time plot observed firing chart. The fuze correction is considered a fuze characteristic, not a correction for weather conditions.

CHAPTER 21

CALIBRATION

Section I. GENERAL

357. Introduction

a. Calibration is the comparison of the muzzle velocity of a given piece with some accepted standard performance. That standard may be selected arbitrarily from the performance of a group of weapons being calibrated together, as in *comparative calibration*, or it may be the standard defined in the firing tables, as in *absolute calibration*.

b. Calibration makes it possible to group cannons of a given caliber and of nearly equal muzzle velocities into one battery so as to reduce the frequency with which individual piece corrections must be applied.

c. Calibration also serves the following purposes:

- (1) It permits the determination and application of corrections to compensate for variations in muzzle velocity developed by individual pieces.
- (2) It provides muzzle velocity data for use with either the met plus VE technique in a new position or the predicted fire technique.
- (3) It serves as a standard against which later VE's computed from registration and concurrent met data may be measured to determine validity.

d. Of the three purposes enumerated in c above, all may be accomplished by absolute calibration. Comparative calibration serves only the purpose listed in c(1) above.

358. Types of Calibration

a. Calibration can be accomplished with the aid of a muzzle velocity measuring device called a chronograph. When a chronograph is not available, it can also be performed with fall of shot procedures of varying complexity. Both techniques result in a variation from the ac-

cepted standard performance expressed in feet per second or meters per second. The unit of measurement of the variation (feet or meters) is the same as the unit used in the firing table for the weapon. A variation determined by chronograph is called muzzle velocity variation. A variation determined from fall of shot procedures, regardless of the complexity, is called velocity error.

b. Measuring the muzzle velocity developed by a weapon-ammunition combination results in *absolute calibration data*.

- (1) Muzzle velocity variations (MVV) can be used to tie groups of weapons together provided a common lot of ammunition is used. Developed muzzle velocity is a function of two variables—the weapon and the ammunition—and, in order to use one as a basis of reference, the other must be kept constant. A group of weapons calibrated with a chronograph will be considered in a state of absolute calibration with respect to firing table standards if a common lot of ammunition is used.
- (2) The VE determined from a fall of shot absolute calibration will not match muzzle velocity variation determined from an instrumental absolute calibration, unless the ballistic coefficient of the projectile lot is standard. Only if the ballistic coefficient change (BCC) is known and, therefore, can be stripped from the fall of shot data as one of the nonstandard conditions, will the VE determined be absolute in the true sense. However, despite an unknown ballistic coefficient, the VE determined from fall of shot is valid for use with the met plus VE technique.

359. Chronograph Support

a. Chronograph support to calibrate field artillery pieces is provided by ordnance teams and by teams organic to field artillery units. If chronograph support organic to the field artillery is utilized, it is desirable to conduct calibration in coordination with other scheduled firings so that ammunition need not be expended specifically to calibrate.

b. Equipment used by ordnance teams will be one of two types, either the skyscreen or the radar doppler. Skyscreen equipment is a set of photoelectric cells which are placed along a carefully surveyed base. The base is established under a prolongation of the tube. Passage of the projectile overhead changes the light intensity striking the cells which in turn activates an electronic timer. The ordnance team computes the mean developed muzzle velocity of the rounds fired from each piece. The unit must determine, and compensate for, the effect of nonstandard propellant temperature and projectile weight to determine the corrected muzzle velocity. The unit then must subtract the corrected muzzle velocity from the firing table standard muzzle velocity to derive the muzzle velocity variation.

c. Chronographs of the radar doppler type are available to ordnance teams and are organic to field artillery units. They are more flexible than skyscreen equipment. The radar doppler equipment is capable of day or night operation. It is ideally suited for use during tactical situations. Accuracy attained with the radar doppler chronograph is equal to the accuracy attained with the skyscreen chronograph.

360. Frequency of Calibration

a. The type and caliber of weapon that is being fired and the frequency (by charge) of firing govern the need for calibration. All new tubes should be calibrated as soon after receipt as possible. Thereafter any weapon in service should be recalibrated at least annually. If a great deal of firing takes place, recalibration may be needed often. If an accurate and reliable record of the change in VE determined from registrations and concurrent met data is maintained, recalibration may not be needed

until the velocity loss becomes excessive. Wear tables can also give a general indication of the need for recalibration.

b. Ordnance teams are equipped to make wear measurements for all cannons except the 280-mm gun. The equipment used is a pullover gauge. This gauge allows a precise measurement of the distance between the lands in the bore near the start of rifling. Tube wear in this region is a fair indication of remaining tube life. Wear measurement should not be substituted for calibration, but can be used to detect extremes in velocities within a group of weapons. However, there is little reliability in a VE constructed through these extremes. Pullover gauge readings can be used to group weapons initially when immediate calibration is not feasible. Changes in the readings may be used as a guide in scheduling recalibration.

c. Availability of the radar doppler chronograph organic to field artillery units may permit calibration more frequently than once a year. It is desirable to maintain a current muzzle velocity for each major ammunition lot for use in fire for effect fire missions. Ideally, the muzzle velocity for each charge within lot should be known, however, this is rarely possible. Practical considerations usually limit calibration within a lot to the charge or charges which provides the desired coverage of the target area.

360.1. Calibration with the Radar Doppler Chronograph

a. *General.* The radar doppler chronograph organic to field artillery units is the Radar Chronograph Set: M36. It is a portable electronic instrument which measures weapon projectile velocities ranging from 75 to 1860 meters per second. It operates on the basic principle that the frequency of the transmitted radio waves will change when reflected from a moving projectile. The difference in frequency between the transmitted and received signals is measured and converted by electronic circuitry to an indicated velocity which is read directly in meters per second. The chronograph team adjusts the indicated velocity to a muzzle velocity under standard conditions of

drag, air density, propellant temperature and projectile weight. The M36 operates from a vehicle or a ground mount to the rear of the piece being calibrated. Positioning of the set requires only a paced survey. The equipment can follow changes in direction and elevation as fast as the piece can be laid. This speed and lack of extensive preparation permits calibration whenever firing is conducted and an M36 chronograph is available. For a more detailed discussion of the M36, see TM 9-1290-325-12/1 and 12/2.

b. Ammunition. The muzzle velocity which the chronograph team reports is a measure of the shooting strength of a weapon, ammunition and charge combination. It is, therefore, required that sufficient amounts of the same lot of propellant and projectile are available for each piece to be calibrated. It is recommended that for each charge, 10 rounds per light or medium piece and 8 rounds per heavy or very heavy piece be fired during the calibration. This includes provisions for two conditioning rounds (warning rounds), the results of which may be discarded if they result in erratic readings. The calibration can be conducted with fewer rounds consistent with ammunition allowances but with some sacrifice of accuracy and overall reliability.

c. Preparation. Calibration with the M36 chronograph can be conducted under tactical or training conditions. Prior to calibration, arrangements are made for use of the chronograph, and the chronograph team is briefed on the number and location of the weapons to be calibrated. The unit also ascertains that a sufficient amount of the lot of ammunition to be fired is available and that all propellant thermometers to be used are properly tested. On the day of the calibration, all tubes must be clean and dry prior to firing.

d. Selection of Charge. The muzzle velocity variation of a given weapon varies from charge to charge. The only method of determining the muzzle velocity precisely with any particular charge is to calibrate with that charge. Usually, calibration can be accomplished with only one, or at the most two charges; hence, it is necessary to select the charge or charges

which will provide the desired coverage of the ranges most frequently fired.

360.2. Application of MV

a. Grouping of Weapons. Weapons are grouped by MV so that each firing battery has pieces which are as close to each other in shooting strength as the situation permits. In some instances where one or more pieces vary considerably in MV, the next higher artillery headquarters may arrange for appropriate transfer of weapons between battalions having the same caliber.

b. Selection of Standard Piece. Once grouping within the battalion is accomplished, each battery selects a weapon as the base piece. The base piece is the piece nearest in MV to the average of the battery and such that the greatest number of the other battery pieces are within five feet (1.5 meters) per second in MV.

c. Computation of Firing Data.

- (1) The average MV for each battery determined by chronograph calibration is used as an MV input to the Gun Direction Computer, M-18 (FADAC). For a more detailed explanation, see FM 6-3-1, Operation, Gun Direction Computer, M-18, Cannon Application.
- (2) The average MV determined by chronograph calibration for each battery may be used in determining a GFT setting as outlined in paragraphs 353-355. When a position VE or average VE is available from prior registrations and concurrent mets, the VE is preferred to the MVV in making the GFT setting unless the VE is within 5 f/s (1.5 m/s) of the MVV in which case the MVV is used.

360.3. Example Problem

a. A 155-mm howitzer battalion has been issued 18 weapons. Pullover gauge readings provided by Ordnance furnish data to permit an interim distribution of pieces of each battery. This initial distribution is temporary since the wear measurement is only a fair indication of muzzle velocity and used only until calibration is accomplished.

b. An M-36 is available during the unit's first week of live firing. Sufficient ammunition of one lot is arranged for so the decision is made to calibrate all weapons. The S3 determines that charge provides the best range coverage for this and future firings.

c. During the service practice, the missions are so rotated among pieces that the chronograph is able to calibrate each weapon. The readings obtained for piece number one of Battery "A" are—

Round Nr.	Reported MV (m/s)
1	311.7
2	315.9
3	316.0
4	317.2
5	316.6
6	316.1
7	318.8
8	317.3
9	316.5
10	315.7

(1) Rounds number one and seven are discarded as erratic and the remaining eight retained. Number two is used, even though it is a warming round, since it appears to be consistent with the other rounds. The eight rounds are averaged, and the result is the MV for this weapon and ammunition lot.

(2) In the same manner, the MVs are computed for the other 17 pieces in the battalion and the results tabulated.

Btry	Piece Nr.	MV (m/s)
A	1	316.4
	2	311.5
	3	312.7
	4	314.2
	5	315.8
	6	314.6
B	1	310.4
	2	307.3
	3	309.3
	4	308.5
	5	313.6
	6	309.7
C	1	304.1
	2	309.1
	3	306.8
	4	305.0
	5	309.0
	6	306.4

(3) The MV is converted from m/s to f/s through use of the formula—

$$\text{Meters} \times 3.281 = \text{Feet}$$

and the weapons are listed in order of decreasing MV.

Piece Nr.	MV (m/s)	MV (f/s)
A1	316.4	1038
A5	315.8	1036
A6	314.6	1032
A4	314.2	1031
B5	313.6	1029
A3	312.7	1026
A2	311.5	1022
B1	310.4	1018
B6	309.7	1016
B3	309.3	1015
C2	309.1	1014
C5	309.0	1014
B4	308.5	1012
B2	307.3	1008
C3	306.8	1007
C6	306.4	1005
C4	305.0	1001
C1	304.1	998

(4) The final MV's are the basis for regrouping weapons. Suppose that the unit SOP requires long-shooting weapons be in "A" battery, medium-shooting weapons in "B" battery and short-shooting weapons in "C" battery. The weapons in paragraph 3 are regrouped by placing the first six (longest-shooting) in "A", the next six in "B" and the last six in "C". Note that most of the weapons were properly grouped on the basis of pull-over gauge readings but that some transferring is required. Battery "A" weapons now consist of:

Piece Nr.	MV (f/s)
A1	1038
A2 (formerly B5)	1029
A3 (formerly A6)	1032
A4	1031
A5	1036
A6 (formerly A3)	1026

(5) Piece number A4 is designed base piece. It is close to the average MV of the battery, and this arrangement requires that only A1 have special corrections applied since it is the only weapon whose MV varies by more than 5 f/s from the base piece. The

exchange of piece numbers between A3 and A6 as shown is not absolutely necessary. It is done in this case to show that the weapon with MV 1032 (regardless of its number) is in the center platoon with A3 because it is closest in shooting strength and provides a close grouping in the adjustment phase of will-adjust missions.

360.4. Calibration of Other Lots

a. General. It is frequently desirable to calibrate more than one major lot. If it is suspected that a considerable loss of MV has occurred since the unit last calibrated, calibration should be accomplished for all weapons. If, however, the suspected loss of MV is small, calibration may be limited to the base piece of one or more batteries.

b. Conduct of Calibration. If relatively few rounds have been fired since the last calibration, a MV for a new lot may be computed for all weapons by comparing the chronograph calibration results of the new lot with the MVs of the lot last calibrated.

c. Example Problem. Assume that a new major lot is to be calibrated in "A" battery. Wear tables show that the loss in MV since the last calibration is minor and it is decided to calibrate the base piece during a registration. Met data is available for use in computing the fall of shot VE from the registration.

- (1) The MV reported by the M-36 chronograph team is 311 m/s (1019 fs).
- (2) Compare the piece MV for the new lot with the piece MV (1031 f/s) obtained when all weapons were calibrated to obtain a difference in MV.

$$1019 \text{ f/s} - 1031 \text{ fs} = -12 \text{ f/s}$$

- (3) Algebraically add the difference (-12 f/s) to the calibration MV of each piece.

$$A1 \ 1038 + (-12) = 1026 \text{ f/s}$$

$$A2 \ 1029 + (-12) = 1017 \text{ f/s}$$

$$A3 \ 1032 + (-12) = 1020 \text{ f/s}$$

$$A5 \ 1036 + (-12) = 1024 \text{ f/s}$$

$$A6 \ 1026 + (-12) = 1014 \text{ f/s}$$

- (4) The resulting figures are the MVs for each weapon for the new lot.
- (5) Compute the VE from the concurrent registration as illustrated in paragraph 341-347. Assume that the VE is computed to be -9 f/s .
- (6) Subtract the base piece MV (1019 f/s) determined by calibration from the standard MV (1020 f/s) to obtain a muzzle velocity variation (MVV).

$$1020 - 1019 = -1 \text{ f/s}$$
- (7) Compare the MVV with the VE.

Since the difference is greater than 5 f/s, the MVV is used with FADAC and the VE with graphical equipment whenever the new lot is fired.

360.5. Records

A record of each lot number of ammunition and associated MV could be an aid to the operations officer. It is possible that the same lot could be issued after an interval of time has passed, and a knowledge of the performance of the lot may eliminate the need for calibration. This is particularly true when the unit does not fire sufficient full service rounds to materially decrease the shooting strength of its pieces.

Section II. FALL OF SHOT COMPARATIVE CALIBRATION

361. Preliminary Considerations

a. General. Comparative calibration is based on the premise that the total effects of non-standard conditions (except velocity deviation from standard) have equal influence on the locations of the centers-of-impact. This premise assumes that the difference in range between CI's is an indication of the difference in velocity. This assumption is valid only within certain limits. For example, it does not mean that weather conditions can be ignored. Relatively stable wind is a condition which must be sought for calibration; and a fall of shot calibration, either comparative or absolute, should not be attempted during the passage of a weather front.

b. Ammunition. Regardless of recent improvements made in the manufacture of ammunition, there remains a significant difference of performance between lots both with respect to propellant velocity and projectile efficiency. It is recommended that 10 rounds per light or medium piece and 8 rounds per heavy or very heavy piece be fired during the calibration; this includes 2 rounds for conditioning the piece (warming rounds). The calibration can be conducted with fewer rounds consistent with ammunition allowances but with some sacrifice of overall reliability. The propellant and the projectile must each be of a single lot; however, if the fuzes are not available in a single lot, it is permissible to calibrate with fuzes of the same type from different lots.

c. Optimum Charge. The VE (or MVV) of a given weapon will vary from charge to charge. The only method of determining the VE (or MVV) precisely with any particular charge is to calibrate with that charge. However, it is rarely possible to calibrate all weapons with all charges. Usually, calibration is accomplished with only one charge, and hence,

it is necessary to select the charge which will cover the ranges most frequently fired. Grouping of weapons must be based on calibration with one charge. Comparative calibration data determined with one charge work fairly well as a basis for individual piece corrections for all other charges for howitzers but not as well for guns. Absolute calibration data are valid only for the specific charge fired.

d. Quadrant Elevation. When fall of shot calibration is being conducted, the weapon should be calibrated at a quadrant elevation between 240 and 460 mils. A low quadrant elevation minimizes the effect of nonvelocity elements absorbed into the velocity error.

e. Emplacement of Weapons. The weapons to be calibrated should be emplaced in a level position area with about 2 feet between trails of adjacent pieces when spread. Cant must be eliminated since laying for quadrant elevation will be with the gunner's quadrant. The weapons may be laid for direction by any of the methods described in chapter 4. The target area should be level and, if at all possible, should be at about the same altitude as the position area. The weapons should be located to a survey accuracy of not less than 1:1,000 (TM 6-200).

f. Observation. If possible, coordination should be effected with the target acquisition battalion which will normally provide the required flash base from which the center of impact achieved by each weapon is determined. Organic observation may be used, provided the observers are trained and equipped to provide the high degree of accuracy required for fall of shot calibration. When organic observation is used, four OP's should be installed, each equipped with a battery commander's telescope. The OP's must be located to a survey accuracy of not less than 1:1,000 and tied to a common reference point located with the same accuracy

(TM 6-200). Each observer will record both azimuth and vertical angle for each round. Care must be exercised in recording so that rounds can be related to their respective pieces. An erratic round can be defined as one which falls more than four range probable errors away from the center of impact of the rounds fired. A round which obviously does not fit the pattern of the remaining rounds should be classified as erratic and should not be included in the location of the center-of-impact. This necessitates a quick check of azimuths recorded by the two flank observers before releasing a piece from the calibration site. If, for the same round, both of these observers recorded an azimuth quite different from all others in that center-of-impact, then an additional round should be fired from that piece. The decision to fire additional rounds is made by the officer in charge.

g. Accuracy. To insure maximum accuracy, all personnel should be briefed on the importance of the calibration. A reliable system of communications and exchange of commands, data, and information should be worked out. An SOP should be developed for the conduct of firing. It is especially important that bubbles are centered exactly before each round is fired. The pieces should be serviced and checked to insure that they are in proper firing condition. A bench-checked (ordnance tested) gunner's quadrant should be used on all pieces. At least one calibrated powder thermometer per piece should be obtained before the firing.

362. Conduct of Firing

a. Each piece is placed over its surveyed stake. Trunnions are leveled and the pieces are boresighted and then laid. Tubes must be cleaned until free of all oil film and then dried.

b. Orienting data (azimuth and vertical angle to desired CI) for each OP is determined and announced to the respective observers.

c. Chart data from the center of the position area to the desired point of impact are measured from a map. A common deflection and quadrant elevation is determined and is used for all pieces throughout the firing. Fuze quick is always used for calibration.

d. Ammunition should be prepared sufficiently in advance of firing to assure uniform weather

conditioning. Powder temperature of at least four rounds at each piece is measured and recorded immediately prior to firing.

e. Observers are alerted before firing is begun. For each round fired, the number of the piece firing, and ON THE WAY are announced when the piece is fired. SPLASH is announced 5 seconds before impact.

f. Each piece is laid for quadrant elevation by the same gunner's quadrant. Salvo fire is used in order to equalize the weather conditions under which each piece is fired. Sufficient time between rounds must be allowed to enable the observers to locate a round, record the data for that round, and change the orienting data for the next round if necessary (about 30 seconds for the average crew is sufficient).

g. The first two rounds from each piece are conditioning rounds but the observers should pick up, report, and record data as a check of the system and procedures.

h. Firing should be completed as rapidly as possible. In the event of a misfire, the piece is called out, the observers are notified, and firing of the other pieces is continued.

i. Before releasing the pieces, a check with the observers should be made to make sure that data for all rounds has been recorded and to see if any rounds were erratic. Refiring should be accomplished immediately if any rounds were erratic or if the observers missed any rounds.

363. Determination of Range and Altitude to Center-of Impact for Each Piece

a. When the target acquisition battalion provides the flash base, it furnishes the coordinates and altitude of the CI for each piece.

b. When the unit provides its own observation, the S3 must examine the observers' recorded data in order to detect erratic rounds and questionable observer data. After deleting the conditioning rounds and erratic rounds, the CI range for each piece is determined in the following manner:

- (1) Compute the average azimuth from each OP for each piece.
- (2) Form three target area bases by using selected pairs of OP's (fig. 99).

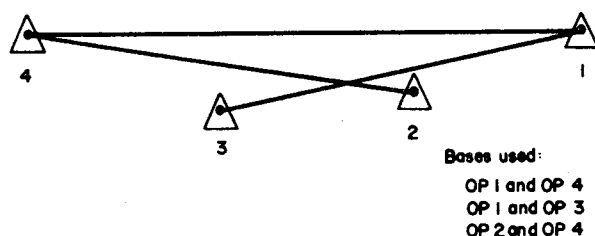


Figure 99. Target area bases.

- (3) Compute three sets of coordinates for each center-of-impact, one from each of the three bases.
- (4) If there is an appreciable difference (20 meters or more radially) in the three sets of coordinates, perform a graphic check (*d* below).
- (5) Average the three sets of coordinates to arrive at the mean CI location.
- (6) Using the coordinates of the pieces and their respective CI location, compute the range to the CI.

c. To determine the altitude of the CI, compute the altitude of CI from each OP and average the four altitudes to determine the mean altitude. (If accurate maps are available, the CI altitude may be measured from the map.)

d. If survey, observer orientation, and observer readings are correct, all rays, as plotted from their respective OP's, will theoretically intersect at a common point. Normally, however, the rays, either for a single round or a center-of-impact, will not intersect but will form a polygon, referred to as the polygon of error. If observer data appears to be of questionable accuracy, a graphical check on the magnitude and nature of the polygon of error will detect it. To accomplish the graphical check, plot all OP's on a gridded sheet to a scale of 1:6,250 and plot the azimuths of the round or center-of-impact in question as rays from the respective OP's. If the graphical check indicates that only one observer is appreciably in error, delete these data and use the data of the other three observers. If more than one observer is in error, then it is best to use the data from all observers as being equally valid because it is not possible to pick out the specific observers at fault. The size of the polygon of error accepted is a good measure of the accuracy of resultant range data

and, hence, the calibration itself. The smaller the polygon, the more accurate is the calibration. A graphical check should be made on the common reference point before firing begins.

364. Adjustment of Ranges for Differences in Altitude

a. In order to obtain a valid comparison of the ranges achieved by the pieces being calibrated, all pieces should be at the same altitude and all centers-of-impact should be at the same altitude. By selecting a level position area, the pieces are established at the same altitude. The centers-of-impact cannot be determined beforehand and, although a relatively level impact area is selected, the altitudes of the CI's may vary. In order to obtain a valid comparison of the ranges achieved by each piece, the measured ranges must be corrected to ranges that would have been achieved had all rounds landed at a common altitude.

b. To correct the measured ranges for difference in altitudes of the CI, the procedure is as follows:

- (1) Select a reference altitude. This altitude may be any convenient altitude. The lowest CI altitude is commonly used as a reference altitude.
- (2) Subtract the reference altitude from the altitude of the CI.
- (3) Multiply the difference in altitude by the cotangent of the angle of fall. (The cotangent of the angle of fall is determined from the "Supplementary Data" table at the measured range to the CI rounded to the nearest 100 meters.) The product is the correction to the range. If the altitude of the CI is greater (less) than the reference altitude, the sign of the correction is plus (minus).
- (4) Add the range correction determined in (3) above to the measured range to determine the corrected range.

365. Selection of the Standard Piece

In a comparative calibration, the piece that achieved the longest corrected range is chosen as the standard piece. Its corrected range is the standard with which the corrected range of the other pieces is compared. The comparative

VE assigned to the standard piece is 0 feet per second.

366. Determination of Comparative Velocity Error

The procedure for determining the comparative VE of a piece is as follows:

a. Determine the difference between the corrected range of the piece in question and the corrected range of the standard piece.

b. Enter the "Ground Data" table at the corrected range (rounded to nearest 100 meters) of the piece in question. Determine the correction for *decrease* in muzzle velocity of 1 foot per second.

c. Determine VE by dividing the difference in range (a above) by the muzzle velocity unit correction (b above). The sign of the comparative VE is always *minus* if the strongest shooting piece is the standard.

367. Correction of Velocity Error for Propellant Temperature Variations

To provide a valid comparative VE, all weapons should have fired ammunition with the same propellant temperature. Precautions should be taken to keep all propellants at the same temperature. If there is any variation in the average propellant temperatures of the individual weapons the comparative VE's determined (par. 366) must be corrected. The final comparative VE of a particular piece is the VE that would have been attained if the ammunition fired by that weapon had the same propellant temperature as the ammunition of the standard piece. The procedure to correct the VE for propellant temperature variation is as follows:

a. Enter "Propellant Temperature" table and determine corrections to muzzle velocity for propellant temperature for all pieces.

b. To determine the correction to VE, subtract (algebraically) the correction to muzzle velocity for propellant temperature of each piece from that of the standard piece.

c. To determine the final comparative VE's, add the corrections (b above) to the respective VE's determined as prescribed in paragraph 366.

368. Example Problem

A 155-mm howitzer battalion has completed firing a fall of shot of comparative calibration using charge 7, quadrant elevation 310. All pieces were at the same altitude. After computation of the range to each CI and its altitude, the following data are available (data for only four pieces are shown):

Piece No.	Measured range (meters)	Altitude of CI (meters)	Average propellant temperature
1	9665	320	83° F.
2	9710	316	80° F.
3	9790	321	80° F.
4	9610	325	78° F.

a. Determine corrected range by correcting for difference in altitudes of CI. The lowest CI altitude (316) is selected as the reference altitude.

Piece No.	Measured range (meters)	Alt of CI (meters)	Difference in altitude	Cotangent of angle of fall	Range correction	Corrected range (meters)
1	9665	320	+4	2.1	+8	9673
2	9710	*316	0	2.1	0	9710
3	9790	321	+5	2.1	+10	9800
4	9610	325	+9	2.2	+20	9630

b. Piece number 3 is selected as the standard piece because its corrected range (9,800) is the greatest.

c. The VE's are then determined.

Piece No.	Corrected range	Difference from std rg	MV unit correction	VE
1	9673	-127	6.4	-19.8 = -20 f/s
2	9710	-90	6.4	-14.1 = -14 f/s
3	9800	0	-----	0 = 0 f/s
4	9630	-170	6.3	-27.0 = -27 f/s

d. The final VE's are determined by correcting for propellant temperature (PT).

Piece No.	PT	Correction to MV for PT	Correction to VE for PT	VE	Final VE
1	83° F.	+6	-1	-20	-21 f/s
2	80° F.	+5	0	-14	-14 f/s
*3	80° F.	+5	0	0	0 f/s
4	78° F.	+4	+1	-27	-26 f/s

369. Comparative Calibration by Battery

a. At times it will be necessary to conduct a comparative calibration with each battery calibrating on a different day rather than the whole battalion calibrating at one time.

b. When comparative calibration is conducted at battery level, the procedures in (1) through (3) below are used to convert the separate calibrations to a common calibration

for the battalion. This calibration is necessary in order to properly group the weapons within the battalion.

- (1) The first battery to calibrate its weapons also calibrates one piece from each of the other two batteries. These pieces will be used later with their respective batteries as control pieces.
- (2) Each separate calibration is conducted and computed as outlined in paragraphs 361 through 367.
- (3) When all batteries have been calibrated, different sets of data are adjusted to a common level by applying a correction to the VE's of the second and third batteries to calibrate. The correction is the number of feet per second required to bring the VE of the control piece when calibrated with its own battery to the VE of the control piece when calibrated with the first battery.

c. An example of adjusting separate battery calibrations to a common level is given in (1) through (6) below.

- (1) Respective battery VE's (Battery A is calibrated first; Battery B, second; and Battery C, third) are as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A-1-----	0	B-1 ^a -----	-8	C-1 ^b -----	-5
A-2-----	-4	B-2-----	-3	C-2-----	-1
A-3-----	-7	B-3-----	0	C-3-----	-6
A-4-----	-8	B-4-----	-5	C-4-----	-7
A-5-----	-12	B-5-----	-9	C-5-----	0
A-6-----	-15	B-6-----	-11	C-6-----	-4
B-1 ^a -----	-2				
C-1 ^b -----	-9				

^a Battery B control weapon.

^b Battery C control weapon.

- (2) In order to adjust the VE's of Battery B, note that +6 f/s must be added to the VE for B-1 to bring it to the VE obtained with Battery A; hence, +6 f/s must be added to all VE's in Battery B.

- (3) Similarly, for Battery C an additional -4 f/s is required to bring the VE of C-1 to the VE it obtained with Battery A; hence, -4 f/s must be applied to all VE's in Battery C.
- (4) By using these correction factors ((2) and (3) above), the calibration data can be rewritten (adjusted to a common level) as follows:

A		B		C	
Weapon	VE	Weapon	VE	Weapon	VE
A-1-----	0	B-1-----	-2	C-1-----	-9
A-2-----	-4	B-2-----	+3	C-2-----	-5
A-3-----	-7	B-3-----	+6	C-3-----	-10
A-4-----	-8	B-4-----	+1	C-4-----	-11
A-5-----	-12	B-5-----	-3	C-5-----	-4
A-6-----	-15	B-6-----	-5	C-6-----	-8

- (5) The weapons can now be listed in order of decreasing shooting strength and the VE's adjusted so that the strongest shooting weapon has a VE of 0; the correction required to bring the strongest shooting piece to 0 must be applied similarly to all weapons.

Order of strength	First adjusted VE	Final adjusted VE
B-3-----	+6	0
B-2-----	+3	-3
B-4-----	+1	-5
A-1-----	0	-6
B-1-----	-2	-8
B-5-----	-3	-9
A-2-----	-4	-10
C-5-----	-4	-10
B-6-----	-5	-11
C-2-----	-5	-11
A-3-----	-7	-13
A-4-----	-8	-14
C-6-----	-8	-14
C-1-----	-9	-15
C-3-----	-10	-16
C-4-----	-11	-17
A-5-----	-12	-18
A-6-----	-15	-21

- (6) The final adjusted VE's are the basis for regrouping the weapons. They represent comparative calibration equal to a battalion-type calibration.

Section III. FALL OF SHOT ABSOLUTE CALIBRATION

370. Preliminary Considerations

a. Nonstandard Conditions. The effects of muzzle velocity must be isolated from the effects of all other nonstandard conditions; however, certain deviations from this basic requirement are accepted in present techniques and will be noted. Careful preparation must be made for obtaining and using met data. Coordination between the officer in charge of the calibration and the officer in charge of the met station is essential. The met station is ideally located at a point between weapon and target and at such a position that the balloon would pass as near the summit of the trajectory as possible. The time of the met message and time of firing should be coordinated.

b. Selecting the Quadrant Elevation. The QE fired should be selected so that the maximum ordinate will be equal to an altitude of a line number of the met message. The method of bringing an acceptable QE (240 to 460 mils) into agreement with a line number of the met message involves the use of the "Supplementary Data" table of the firing table. The following example illustrates the method of selecting the QE to be fired in calibrating a 155-mm howitzer with charge 5:

Altitude of Met Line Numbers	
Line 2	500 meters
Line 3	1000 meters
Line 4	1500 meters
Line 5	2000 meters

From the "Supplementary Data" table, a maximum ordinate of 500 meters results in a horizontal range of approximately 6,000 meters. The quadrant elevations for ranges in the vicinity of 6,000 meters are in the vicinity of 304 mils, a good QE for calibration. The range corresponding to a maximum ordinate of 500 meters is 5,963 meters. The corresponding QE is 301.5 mils. For convenience, this QE can be rounded to 300 mils for firing the calibration.

c. Selecting Pieces for Calibration. It is sometimes desirable to bring only a limited

number of pieces into a state of absolute calibration. Preferably, three pieces per battalion are selected, although one is sufficient. Pieces selected should be the base pieces if determined, or, those with average wear measurement within each battery. If comparative calibration data are known or later determined, all pieces can be brought into an acceptable state of absolute calibration. An example problem is shown in paragraph 373a.

d. Other Considerations. Except as stated herein, preliminary considerations are the same as those for comparative calibration.

371. Conduct of Firing (Absolute Calibration)

An absolute calibration is conducted in the same manner as a comparative calibration, except that salvo fire is not used. Each piece will complete the firing of its CI before the next piece fires. Each CI should be fired as rapidly as possible consistent with the capabilities of the weapon and personnel involved in order to minimize range effects due to changes in weather. Speed should not, however, take precedence over accuracy.

372. Computation of Absolute Velocity Error

a. To compute the VE, first locate the CI for each weapon by using the method described in paragraph 363. Compute the developed CI range. Compute site, using the difference in altitude between the piece and CI. Subtract the site from the QE fired to determine the elevation fired. Enter the "Ground Data" table and interpolate for the range corresponding to the elevation. This is the standard horizontal range that would have been achieved if all conditions had been standard at the time of firing. Subtract the developed CI range from the standard (firing table) range. The resultant difference in range is the range correction necessary to compensate for all nonstandard conditions at the time of firing.

b. Compute range corrections for all known nonstandard conditions, except powder temperature, using met data taken at time of firing. All unit corrections are determined at the range (nearest 100 meters) to the CI. The line number is that corresponding to the QE fired.

c. The met range correction is subtracted from the total range correction determined as described in *a* above. The result is the correction in meters to compensate for ΔV . The ΔV is computed by dividing the ΔV range correction by the MV unit correction (determined at CI range). If the ΔV range correction is plus (minus), the MV unit correction is taken from the Decrease (Increase) column. VE is determined by subtracting the muzzle velocity correction for propellant temperature from ΔV . The powder temperature used is the average of all powder temperatures recorded at the piece.

Example: 155-mm howitzer, charge 5, white bag.

CI range.....5,530 meters
 Site.....+ 6.4 mils
 QE fired.....300 mils
 Elevation.....293.6 mils (300-6.4)

Standard range corresponding to elevation 293.6 mils = 5,844 meters. Total range correction to compensate for all nonstandard conditions is +314 meters (5,844 - 5,530).

Met range corrections (line number corresponding to QE 300; unit corrections at range 5,500) = +172 meters.

ΔV range correction = +142 meters (314 - 172).

Unit correction for muzzle velocity (*Decrease* column, range 5,500) = 4.6.

$$\Delta V = +142/4.6 = -30.9 \text{ f/s} = -31 \text{ f/s.}$$

Powder temperature 53° F.

Correction to muzzle velocity for propellant temperature = -5.

$$VE = -26 \text{ f/s } (-31 - (-5)) = -26 \text{ f/s.}$$

d. The VE of -26 feet per second in the example above approximates absolute calibration for this weapon-ammunition combination. However, if such a calibration is conducted in conjunction with an ordnance chronograph calibration, the officer in charge should not be unduly alarmed if the muzzle velocity variation computed is of a different magnitude. Primary reasons for this difference are—

- (1) A projectile lot which is more or less efficient in overcoming air resistance than the projectile lot used to construct the firing table shows up as an increase or decrease in range not otherwise accounted for.
- (2) Errors in the met data used.
- (3) Limitations of present computational procedures and firing tables.
- (4) Errors in survey.
- (5) Errors in the QE used (to include barrel curvature).

e. The officer in charge should examine the magnitude and sign of the differences (VE minus MVV) and recheck computations for any sample that deviates from the pattern followed by most of the weapons. In the following example, piece 4 should be rechecked.

Piece No.	VE	MVV	Difference
1.....	-24	-18	-6
2.....	-30	-25	-5
3.....	-22	-15	-7
4.....	-37	-21	-16
5.....	-27	-23	-4
6.....	-25	-20	-5

Section IV. REDISTRIBUTION OF WEAPONS

373. Grouping of Pieces According to Velocity

a. *Grouping After Calibration by Fall of Shot.* To group the pieces, prepare a list, by tube number, of all pieces calibrated, ranging in order from the strongest shooting piece to the weakest. These pieces should then be assigned to batteries based on their shooting strength;

i.e., the strongest one-third in one battery (normally A), the weakest one-third in another battery (normally C), and the remaining one-third in the remaining battery (normally B). Within batteries, the base piece should be the piece with the shooting strength nearest the battery average. To equalize wear among the tubes in service, the longest shooting pieces should be

habitually assigned missions which may call for only part of the pieces of the battery. The following examples illustrate the method of grouping pieces according to shooting strength:

Tube No.	VE comparative calibration	Adjustment of VE's to absolute scale	Battery ^a
51180.....	0	-11	A 1
51242.....	-1	-12	A 2
51177 ^a	-3	-14	A (base piece ^b)
51359.....	-4	-15	A 4
51628.....	-5	-16	A 5
51032.....	-5	-16	A 6
51768.....	-6	-17	B 1
51535.....	-8	-19	B 2
51640.....	-10	-21	B (base piece ^b)
51819.....	-11	-22	B 4
51225.....	-12	-23	B 5
51275.....	-13	-24	B 6
51393.....	-14	-25	C 1
51410.....	-14	-25	C 2
51733.....	-15	-26	C 3
51366.....	-16	-27	C 4
51136.....	-19	-30	C (base piece ^b)
51250.....	-22	-33	C 6

^a Absolute calibration performed with this tube.

^b If the designation of the average piece as the base piece causes calibration correction to be carried on one or more of the pieces, another piece may be designated as the base piece.

^c Assignment to batteries only; does not infer piece numbering within batteries.

Note. When more than one weapon in a battalion is in a state of absolute calibration with the same ammunition combination, the adjustment of VE's to the absolute scale employs the mean difference between the comparative VE and respective absolute VE, as shown below:

Piece No.	Comparative VE	Absolute VE	Difference
1.....	0	-12	-12
2.....	-1	-14	-13
3.....	-3	-14	-11
		Mean	-12

Therefore, -12 feet per second should be applied to the comparative VE's of all weapons to adjust to the absolute scale.

b. Grouping After Calibration by Chronograph. The results of chronograph calibration (MVV's) are absolute calibration data. These data, when available, permit the most effective grouping, and are also the basis for the most reliable corrections for variations in shooting strength between weapons. When MVV's and VE's of either the comparative or absolute type are determined concurrently, the MVV's should be used as the basis for grouping and subsequent computation of individual piece corrections.

374. Computation and Application of Calibration Corrections

a. Once the weapons have been calibrated and grouped, corrections must be applied to compensate for the difference in shooting strengths between the base pieces of the batteries within the battalion and for differences between the base piece and other weapons within the battery. Computing and applying these corrections are explained in chapter 22.

b. When either MVV's or VE's of the absolute type are to be used as a basis for computation in the met plus VE techniques, the following factors should be considered:

- (1) When both MVV's and VE's are available from the same calibration, the VE's will normally prove more successful in present techniques. The VE's at least partly compensate for variation in projectile lot efficiency (from the firing table lot) and barrel curvature, whereas the MVV's do not.
- (2) VE's are subject to errors of met data and survey. They are also subject to limitations of present computing procedures.
- (3) The MVV or VE used in this respect is valid only for the weapon-ammunition combination for which it has been determined.

c. The following rules should be used as a guide in applying calibration data when MVV's and VE's are both available:

- (1) MVV's are preferred to either type of fall of shot calibration data for grouping pieces and computing individual piece corrections.
- (2) VE's of the absolute type are preferred to MVV's for computing corrections to firing data as in met plus VE techniques.
- (3) If MVV's and comparative type VE's only are available, the MVV's are preferred for all aspects of application (grouping, individual piece corrections, and corrections to firing data).

Section V. HEAVY ARTILLERY

375. General

The procedures for calibrating heavy and very heavy artillery, grouping the pieces, and the subsequent computation and application of calibration corrections are the same as for light and medium artillery. However, with heavy and very heavy artillery, excluding the 8-inch howitzer, loss in muzzle velocity per round fired is significant. Unless the same number of rounds is fired by all weapons of a battery, calibration data must be altered periodically. It is, therefore, necessary to maintain an accurate record of calibration data, subse-

quent firing, and corrections applied to calibration data. The record of firing is maintained in the weapon record Data, DA Form 2408-4. A complete record of calibration data is kept by the battery and by the battalion.

376. Wear Tables

Wear tables may prove helpful in filling in the gaps between calibrations. Wear tables estimate the erosion that a gun tube will be subjected to as a result of firing a certain number of rounds with specified charges. From this estimated erosion, the loss in muzzle velocity may be approximated.

CHAPTER 22

CALIBRATION, POSITION, AND SPECIAL CORRECTIONS

Section I. CALIBRATION CORRECTIONS

377. General

Calibration corrections are corrections to compensate for the variations in the shooting strength of the pieces in a unit. Calibration corrections are used primarily—

a. To derive GFT settings for nonregistering batteries from the registration of one battery.

b. In combination with position corrections when special corrections are required.

378. Determination of GFT Settings for Nonregistering Batteries

a. When only one battery of a battalion equipped with weapons of the same caliber is allowed to register, the GFT setting of the registering battery is used by the nonregistering batteries in the absence of any better information. If calibration VE's of the base pieces of the batteries are known, these VE's may be applied to obtain GFT settings for the nonregistering batteries which will approach the accuracy of GFT settings that would have been obtained if all batteries had registered.

b. To determine the GFT setting for a non-adjusting battery, the procedure is as follows:

- (1) Determine the comparative VE of the base piece of each nonregistering battery by subtracting VE of the base piece of registering battery from the VE of the base piece of the battery in question.
- (2) Determine a VE range correction by multiplying the comparative VE ((1) above) by the muzzle velocity unit correction corresponding to the chart range for the registering battery.
- (3) Determine the corrected range for the nonregistering battery by adding the VE range correction to the GFT range of the registering battery.

(4) Determine the elevation corresponding to the corrected range ((3) above).

(5) The GFT setting is constructed by placing the hairline over the chart range to the registration point for the registering battery and drawing the elevation gageline over the elevation determined in (4) above.

(6) The time gageline is drawn over the fuze setting obtained by applying the registration fuze correction to the fuze setting corresponding to the elevation determined in (4) above.

Example: Battery B (155-mm howitzer) has registered and determined the following GFT setting: GFT B: charge 5, lot YS, range 6820, el 368. The VE's for the base pieces are—

A —3 f/s
B —10 f/s
C —16 f/s

The comparative VE's of the base pieces for A and C are—

A +7 f/s (—3—(—10))
C —6 f/s (—16—(—10))

The muzzle velocity unit corrections are—

A —5.2 (increase column)
C +5.5 (decrease column)

The VE range corrections are—

A —36 meters
C +33 meters

The corrected ranges for A and C then become the GFT range for B plus the range correction.

A $6820 - 36 = 6784 = 6780$
C $6820 + 33 = 6853 = 6850$

Using the GFT setting for B Battery and the corrected ranges determined for A and C, the elevation and fuze setting are read under the appropriate gagelines. The GFT settings are—

GFT A: chg 5, lot YS, rg 6820, el 365.
GFT C: chg 5, lot YS, rg 6820, el 371.

379. Calibration Corrections for Individual Pieces of a Battery

a. Calibration corrections to compensate for the variation in shooting strengths of the pieces of a battery are applied to the quadrant elevation. The individual piece correction is based on the variation of the shooting strength of each piece from that of the base piece.

b. In area fire, calibration corrections should be applied to any piece for which the VE varies by more than 5 feet per second from that of the base piece. Calibration corrections for various ranges may be computed and tabulated on a card which is furnished to the chief of section. The chief of section determines the appropriate correction and applies it to the announced quadrant elevation.

c. When special corrections are to be used to achieve a particular burst pattern, calibration corrections are determined and applied to all pieces in the battery.

d. To determine the calibration correction for an individual piece(s) of a battery, the procedure is as follows:

- (1) Determine the comparative VE of the piece(s) with respect to the base piece by subtracting the calibration VE of the base piece from that of the piece(s) in question.
- (2) Determine the muzzle velocity unit correction from the Ground Data table at the chart range (to the nearest 100 meters) using the Decrease (Increase) column if the sign of the comparative VE ((1) above) is minus (plus).
- (3) Determine the calibration correction in meters by multiplying the comparative VE by the muzzle velocity unit correction.
- (4) Determine the calibration correction in mils by dividing the calibration correction in meters by the *change in range for 1 mil change in elevation* (m/mil). The meters per mil is determined from the Ground Data table at the chart range to the nearest 100 meters.

Example: A 155-mm howitzer battery has been assigned a barrage at a chart range of 7,130 meters. Calibration corrections are to be applied. The comparative VE's from a calibration with charge 5 are as follows:

Piece No.	Calibration VE
1	-7 f/s
2	-9 f/s
3 (base piece)	-10 f/s
4	-11 f/s
5	-14 f/s
6	-14 f/s

Following the procedure described in *d* above, the calibration corrections are computed as follows:

Piece No.	Comparative VE	$\times$	MV unit corr	=	Cal corr (meters)	$\div$	m/mil	=	Cal corr
1	+3	$\times$	-5.4	=	-16	$\div$	13	=	-1 mil
2	+1	$\times$	-5.4	=	-5	$\div$	13	=	0 mil
3	0	$\times$	-----	=	-----	$\div$	---	=	0 mil
4	-1	$\times$	+5.7	=	+6	$\div$	13	=	0 mil
5	-4	$\times$	+5.7	=	+23	$\div$	13	=	+2 mil
6	-4	$\times$	+5.7	=	+23	$\div$	13	=	+2 mil

e. If time fuze is to be used, a calibration fuze correction corresponding to the calibration correction for range (elevation) must be determined and applied. The following proportion may be used to determine the time correction:

$$\frac{\text{Calibration fuze correction}}{\text{Difference in fuze setting for 100-meter range change}} = \frac{\text{Calibration correction (meters)}}{100 \text{ meters}}$$

The difference in fuze setting for a 100-meter range change is determined by entering the Ground Data table with the elevation for the base piece. The difference between the fuze settings corresponding to the two listed elevations which bracket the base piece elevation is the desired difference in fuze setting for a 100-meter range change. If the elevation for the base piece is listed in the firing table, the difference used is that between the fuze setting corresponding to the base piece elevation and that corresponding to the next higher (lower) listed elevation when the calibration correction in meters is plus (minus).

Section II. POSITION CORRECTIONS

380. General

a. Position corrections are corrections for individual pieces to compensate for the difference between the pattern formed by the pieces in the position area and the desired pattern of bursts at the target. Position corrections may be required because of abnormal dispersion or concentration of the pieces or because of the location, size, or shape of the target.

b. As a general rule, position corrections are applied in area missions only if the depth of the position is abnormally great. A deflection difference is usually used in an area mission to correct for an abnormal width of battery.

c. In rare cases, such as positions in mountainous terrain, corrections may be needed for differences in the altitude of pieces. The correction for vertical displacement will be negligible and is ignored unless the terrain is extremely rugged. The correction for the range effect is determined by using the GST to compute the amount of site necessary to correct for vertical displacement of the piece from the battery center. This change in site may be multiplied by the meters per mil from the tabular firing table to obtain the equivalent range correction. The equivalent range correction may also be obtained from the GFT by applying the site as a change in elevation. The range correction obtained is combined with other position corrections to give the total correction.

381. Preparation of M10 Plotting Board for Determining Position Corrections

When the M10 plotting board is used to determine position corrections, the piece locations and desired sheaf must be plotted to scale on the plotting board and an index must be constructed for reading deflections. Prior to plotting the piece locations or constructing the deflection index, the centerline on the transparent disk (red 32 at top) must be alined so that it coincides with the arrow on the gridded base of the board.

a. The piece locations contained in the battery executive officer's report (oral or sketch) (fig. 100) are plotted on the transparent disk of the plotting board. To facilitate measurement, each small square of the base is assigned a value

of 5 meters. Pieces are plotted with the center of the board representing the battery center; for example, a piece which is 30 meters right of, and 20 meters behind, the battery center, would be plotted 6 squares right of, and 4 squares in rear of, the center of the board.

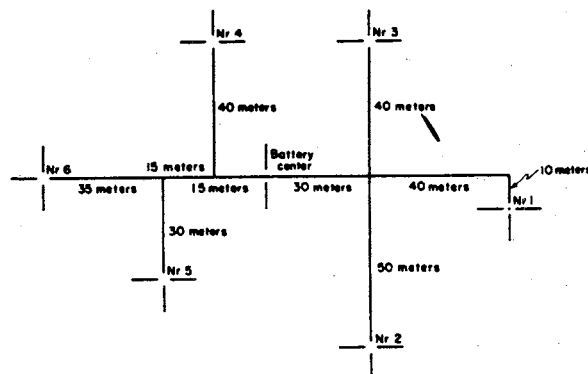


Figure 100. Executive officer's sketch of an abnormal battery position.

b. An index for reading deflections is placed on the base opposite the deflection at which the aiming posts were emplaced. The second of the three rows of figures (printed in red) on the rotating disk is used.

c. Lines may be drawn on the board parallel to the arrow indicating the direction of fire, with the proper distance between them depending on the type of sheaf desired ((1)-(3) below), and to the same scale used in plotting piece locations (a above) (fig. 101).

- (1) *Open sheaf*—lines are parallel to direction of fire and equally spaced corresponding to the effective width of the burst.
- (2) *Converged sheaf*—no lines are needed; the center of the board represents the convergence of the sheaf.
- (3) *Special sheaf*—each desired point of burst would be plotted.

382. Computation and Application of Position Corrections

a. After preparation of the M10 plotting board has been completed, position corrections in meters for deflection and range for each piece of the battery may be graphically obtained for any

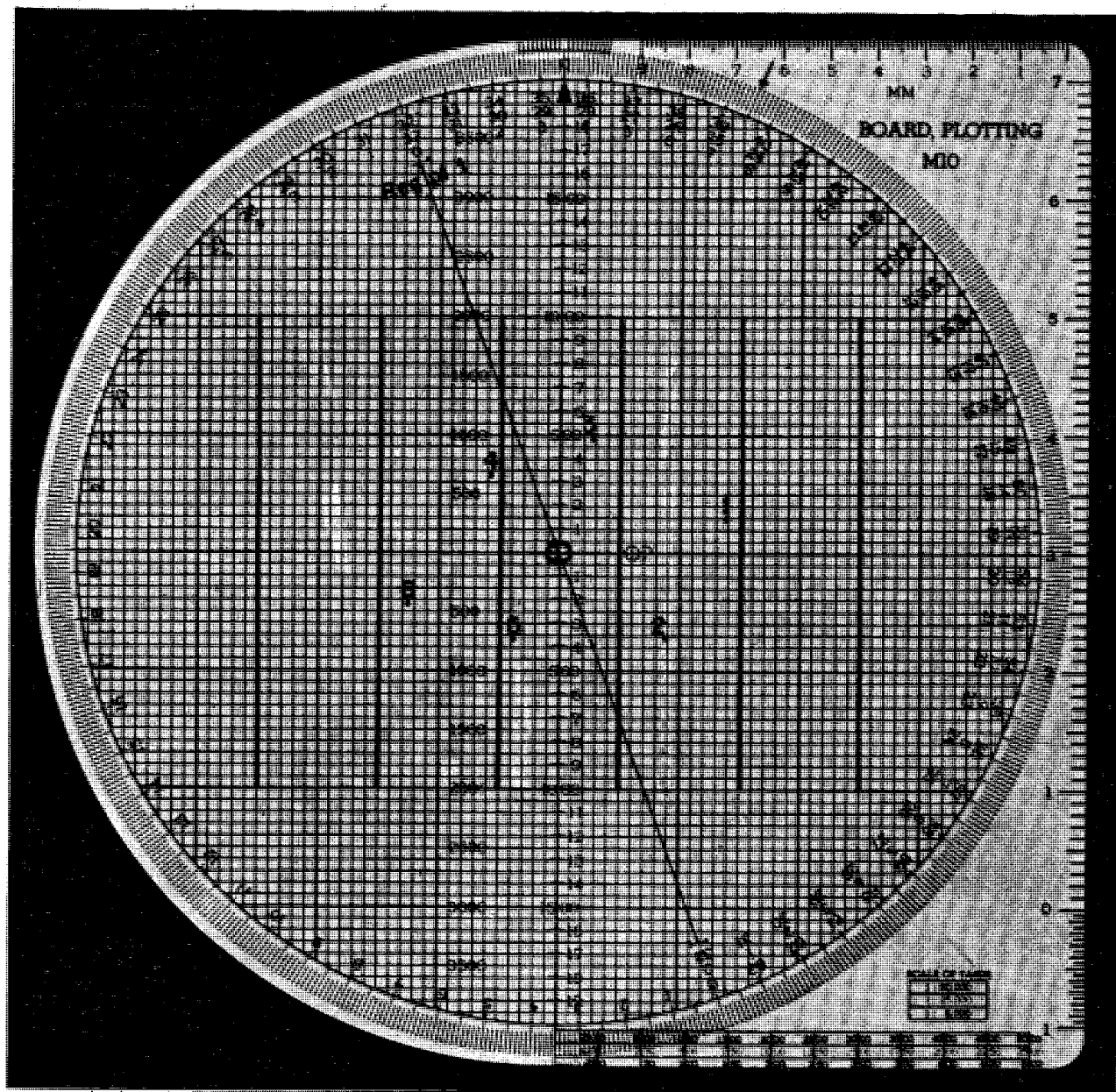


Figure 101. Use of M10 plotting board.

desired direction of fire. The plotted positions correspond to the uncorrected burst positions as well as piece positions.

b. Direction of fire is set off on the M10 plotting board by rotating the transparent disk until the desired deflection is opposite the constructed deflection index.

c. Deflection correction in meters for each piece (burst) corresponds to the distance and direction (right or left) between the plotted burst and its appropriate place in the constructed sheaf. Starting with the right burst, each burst is moved to the nearest sheaf line, with no more than one burst to a line. The bursts need not be placed in the sheaf in the numerical order of piece numbers. The correction in meters is converted to mils by dividing the shift in meters by the chart range to the nearest thousand meters (mil relations).

d. The range correction in meters for each piece (burst) corresponds to the distance and direction (over or short) between the plotted burst and the line at chart range (center of board), perpendicular to the direction of fire.

- (1) Range correction in meters is converted to mils of elevation by dividing by the meters per mil of elevation factor.
- (2) Range correction is converted to a time correction in the manner described in paragraph 379e.

Example: A 155-mm howitzer is laid and aiming posts have been placed out at deflection 2,400. The pieces are distributed as shown in figure 100. The barrage assigned to the battery is at a chart range of 5,710 meters. The chart deflection to the barrage is 2,050 mils. The long axis of the barrage is perpendicular to the direction of fire. Determine position correction, using charge 5, fuze M51 open sheaf.

- (1) Remove disk from M10 plotting board and draw 6 lines parallel to the arrow 50 meters apart, with the 2 centerlines 25 meters right and left respectively of the arrow. (Scale: 1 small square = 5 meters.)
- (2) Replace the disk and orient the 0-3200 line of the disk over the arrow with the red 32 on the disk at the head of the arrow.

- (3) Plot the pieces on the disk.
- (4) Place a deflection index or the plotting board opposite the red 24 on the disk.
- (5) Rotate the disk until 2050 (center of red scale) is opposite the deflection index.
- (6) Determine the number of meters correction for deflection to move each burst to the appropriate place in the sheaf.
 - No. 1, right 55 meters.
 - No. 2, right 30 meters.
 - No. 3, right 10 meters.
 - No. 4, right 2 meters.
 - No. 5, left 56 meters.
 - No. 6, left 64 meters.
- (7) Convert correction for deflection from meters to mils by dividing the correction in meters by the chart range to the nearest thousand meters.
 - No. 1, right 9 (55/6).
 - No. 2, right 5 (30/6).
 - No. 3, right 2 (10/6).
 - No. 4, zero (2/6).
 - No. 5, left 9 (56/6).
 - No. 6, left 11 (64/6).
- (8) Determine the range correction in meters required to bring each burst to the line at chart range perpendicular to the direction of fire.
 - No. 1, -14 meters.
 - No. 2, +37 meters.
 - No. 3, -48 meters.
 - No. 4, -33 meters.
 - No. 5, +38 meters.
 - No. 6, +22 meters.
- (9) Convert range correction in meters to mils of elevation by dividing by the meter per mil factor for the chart range to the nearest 100 meters.
 - No. 1, -1 mil (-14/15).
 - No. 2, +2 mils (+37/15).
 - No. 3, -3 mils (-48/15).
 - No. 4, -2 mils (-33/15).
 - No. 5, +3 mils (+38/15).
 - No. 6, +1 mil (+22/15).

e. Position corrections also may be applied by using the GFT in conjunction with the M10 plotting board.

- (1) Deflection correction for each piece is computed and applied as in *c* above.
- (2) To obtain individual elevations and times to be fired, apply the range correction determined from the M10 plotting board to the chart range. Place

the hairline over the corrected range and read the corrected elevation under the elevation gageline, and the corrected time under the time gageline. If no gagelines exist, read the elevation and time under the hairline.

Section III. SPECIAL CORRECTIONS

383. General

Special corrections are individual piece corrections applied to deflection, fuze setting, and quadrant elevation, in order to place the burst in a precise pattern with the bursts of each piece falling (theoretically) at a planned point on the target. In the rare cases when they are used, special corrections are normally computed at the battalion fire direction center. Special corrections are a combination of calibration corrections and position corrections.

384. Determination of Special Corrections

a. Deflection. The special corrections for deflection are solely position corrections and are determined as prescribed in paragraph 382c.

b. Range (Elevation). The special correction for range for each piece is the sum of its calibration correction in meters and position correction for range in meters. The total correction in meters is then converted to mils of elevation by dividing by the meters per mil factor determined at chart range.

c. Time. The special correction for fuze setting is determined by the following formula:

$$\frac{\text{Special fuze correction}}{\text{Difference in fuze setting for a 100-meter change in range}} = \frac{\text{Special correction for range in meters}}{100 \text{ meters}}$$

The difference in fuze setting for a 100-meter change in range is determined at the elevation to the target before special corrections are applied, using procedure described in paragraph 379e.

d. Range (Correction). When the GFT is used, the special correction for range in meters is applied to the chart range to determine the corrected range. Place the hairline of the GFT

over the corrected range for each piece and read the elevation and time for each piece under the hairline or the respective gagelines if established.

385. Application of Special Corrections

a. Deflection. The special correction for deflection is added to the chart deflection and deflection correction. The total deflection for each piece is announced. If a unit is equipped with gunner's aids and chooses to use them, the special correction for deflection and the deflection correction are combined and announced prior to the common deflection for all pieces in the battery; e.g., CORRECTION, NUMBER 1 (so much); NUMBER 2 (so much); etc.

b. Time. The special correction for time is applied to the common fuze setting, and the total time for each piece is announced.

c. Elevation. The special correction for elevation is added to the common quadrant elevation, and the total quadrant elevation for each piece is announced.

d. Example:

BATTERY ADJUST
SPECIAL CORRECTIONS
SHELL HE, LOT XY, CHARGE 5
FUZE TIME
BATTERY ONE ROUND
DEFLECTION, No. 1, 2449; No. 2, 2450; No. 3, 2450; No. 4, 2453; No. 5, 2449; No. 6, 2452
TIME, No. 1, 21.9; No. 2, 22.2; No. 3, 21.8; No. 4, 21.9; No. 5, 22.4; No. 6, 22.4
QUADRANT, No. 1, 371; No. 2, 376; No. 3, 369; No. 4, 371; No. 5, 380; No. 6, 379

CHAPTER 23

FIRE DIRECTION PROCEDURES

Section I. INTRODUCTION

386. General

The fire direction procedures presented herein are for battalion fire direction. The personnel of the fire direction center (FDC) are assigned specific duties. Those duties are performed in a prescribed sequence and manner to provide efficient fire control.

387. Battalion S2

The battalion S2 is the intelligence officer. FM

6-20 and FM 6-21 contain detailed discussions of his duties. Duties of the S2 which pertain to fire direction are to—

- a. Locate, report, and recommend likely targets to the S3.
- b. Advise the S3 on methods of attacking targets.
- c. Obtain and distribute maps and aerial photographs and assist in target restitution.

Section II. DUTIES OF BATTALION FDC PERSONNEL, GENERAL

388. Organization

The battalion FDC team is composed of the S3, the assistant S3, one chief fire direction computer, one horizontal control operator, one vertical control operator, one computer for each battery organic or attached to the battalion, and the number of radiotelephone operators necessary to monitor and operate the radio and wire communication nets of the battalion. In addition to these members of the battalion FDC team, a switchboard operator, is needed to install and operate the battalion FDC switchboard.

389. Battalion S3 (Assistant S3)

The battalion S3 is the operations and training officer. FM 6-21 contains a detailed discussion of his duties. He is the gunnery officer of the battalion. The S3 plans, coordinates, and supervises the activities of the battalion FDC and fire direction personnel in the batteries and trains the personnel. The assistant S3 must be able to perform the duties of the S3. The duties of the S3, when engaged in fire direction, are to—

- a. Actively supervise the battalion FDC and fire direction personnel in the batteries to insure accurate and timely delivery of fire.
- b. Supervise the functioning of the battalion fire direction wire and radio nets.

c. Inspect the plot of each reported target, decide how to attack the target, and issue the fire order.

d. Direct and supervise the computation and transmission of corrections, such as registration, met corrections, and velocity error (VE).

e. Insure that appropriate fire direction records are maintained.

f. Supervise the preparation and execution of prearranged fires.

390. Chief Fire Direction Computer

The chief fire direction computer is the senior enlisted member of the battalion fire direction center. He must be capable of operating and supervising the operation of the communication facilities within the fire direction center. He must be thoroughly proficient in both communication and gunnery procedures. His specific duties are to—

- a. Supervise all enlisted members of the fire direction center.
- b. Compute registration, met, and velocity error corrections.
- c. Maintain the consolidated record of ammunition supply and expenditures.
- d. Inform the S2 as to the status and progress of fire missions.
- e. Maintain necessary FDC records.

391. Horizontal Control Operator (HCO)

The duties of the HCO are to—

- a. Prepare and maintain the horizontal control chart (grid sheet).
- b. Plot target locations.
- c. Determine and announce the range and deflection.
- d. Determine the size of the angle T and announce it when necessary.
- e. **Assist the VCO and computer in determining replot data.**
- f. **Replot concentrations.**

392. Vertical Control Operator (VCO)

The specific duties of the VCO are to—

- a. Prepare and maintain the vertical control chart.
- b. Maintain a fire capability overlay and a situation overlay.
- c. Plot targets, determine and record their altitudes, and announce the altitudes when required.
- d. Compute the site for each battery and announce that site to the appropriate computer when requested.
- e. Assist the S3 in selecting the basis for corrections; or in selecting charge and lot when the basis for corrections is not to be announced.
- f. Assist the computer **and the HCO** in determining replot data.
- g. Act as a horizontal control operator in the event of multiple missions.
- h. Assist the chief fire direction computer as directed.

393. Computer

The duties of the computer are to—

- a. Record fire requests, fire orders, firing data, corrections, and all other data which the S3 directs and maintain necessary records.
- b. Compute and transmit deflection (i.e., chart deflection plus deflection correction) to the firing battery.
- c. Determine the fuze setting.
- d. Combine the announced site with 20/R (height of burst over range) when required and compute changes in site during the adjustment.

e. Combine the site with the elevation to determine quadrant elevation.

f. Transmit fire commands to the firing battery in the proper sequence.

g. Announce, when acting as adjusting battery computer, corrections to fuze and height of burst to the nonadjusting battery computers.

h. Compute met, VE, special corrections, and deflection differences when directed.

i. Assist in the conduct of registrations and the determination of registration corrections.

j. Determine data for replot with the assistance of the vertical control operator **and the horizontal control operator.**

k. Transmit current chart data and corrections to the battery fire direction center.

l. Construct the deflection correction scale.

m. Record the battery executive officer's report.

n. Prepare data sheets and maintain the record of all data sheets for prearranged fires sent to the firing battery.

394. Switchboard Operator

The switchboard operator must be trained in both FDC and communication procedures. His specific duties are to—

- a. Install and operate the FDC switchboard.
- b. Assist in the installation of radio/wire integration and local FDC circuits.
- c. Prepare and maintain a traffic diagram.
- d. Perform necessary communication checks to insure that FDC circuits operate properly.

395. Radiotelephone Operator(s)

The radiotelephone operator(s) must be trained in both communication and FDC procedures. His specific duties are to—

- a. Operate a telephone or radio in the fire direction center.
- b. Install remote control or radio/wire integration circuits from the radio vehicle to the fire direction center.
- c. Repeat fire missions received by telephone or radio.
- d. Make communication checks as directed.

Section III. SPECIFIC FDC PROCEDURES

396. Charts

a. *S3 Chart.* If the S3 desires, a separate chart is constructed to show the fire capabilities and the locations of firing batteries, forward troop locations, no-fire line, registration points, and met check points. This chart should be a map.

b. *Horizontal Control Chart.* The horizontal control chart is usually a grid sheet on which are plotted the locations of the firing batteries, surveyed observation posts, registration points, met check points, barrages, and targets as ordered by the S3 or requested by the observers. The horizontal control operator (HCO) maintains the horizontal control chart.

c. *Vertical Control Chart.* The vertical control chart is **normally a grid sheet supplemented by a 1:50,000 map** on which are plotted the location of firing batteries, surveyed observation posts, registration points, met check points, barrages, and targets as ordered by the S3 or requested by the observers. During multiple missions, the vertical control charts may be used to produce horizontal data. The vertical control operator (VCO) maintains the vertical control chart. The VCO also maintains the following:

- (1) A map on which is plotted firing battery locations and deflection indexes.
- (2) A fire capabilities overlay.
- (3) A dead space overlay.
- (4) A situation overlay on which are posted the no fire line, friendly locations, and routes of current and scheduled patrols.

d. *Record of Surveyed Data.* For convenience, each chart should have attached to it, a sheet of paper on which are tabulated the coordinates and altitude of each firing battery and all critical points plotted on the chart. In addition, the azimuths on which the batteries are laid, the azimuth of the orienting lines, orienting angles, and the reference azimuths for the surveyed observation posts should be recorded.

397. Equipment

a. *Vertical Control Operator and Horizontal Control Operator.* Each chart operator will have, in addition to the more common equipment such as map pins, plotting needles, colored pencils, etc., a coordinate scale and a range-deflection protractor (fig. 69). In addition, the vertical control operator

will have a graphical site table (GST) for each caliber weapon for which he must compute site.

b. *Computer.* Each computer will have a graphical firing table (GFT) for the caliber and type of weapon for which he is computing.

398. Recording the Initial Fire Request

a. The majority of requests for fire will reach the FDC in the form of an initial fire request from an observer. Missions coming to the battalion FDC by wire or radio are received and read back by a radiotelephone operator. The radiotelephone operator insures that all members of the FDC are alerted to the mission by announcing FIRE MISSION.

b. All computers not actively engaged in another mission record the initial fire request on DA Form 6-16 (FDC Computer's Record) (fig. 102).

399. Plotting the Target Location

When a fire mission is received, each chart operator, unless engaged in another fire mission, will immediately plot the location of the new target. The plot is based, on the method of location used in the initial fire request.

400. Fire Order

a. When a target is plotted, the S3 examines its location relative to the friendly forces, no-fire line, zones of fire, and registration points. From this examination, and considering the factors listed in chapter 30, he decides how to attack the target, unless for some reason the mission should not be fired.

b. The S3 issues a fire order which consists of some or all of the elements listed below. To avoid errors and confusion and to save time, the sequence indicated in (1) through (12) below is followed. Inapplicable elements are omitted. The timely delivery of fire should not be delayed to complete the fire order.

Element	When announced	Example
(1) Battery(ies) to fire.	Always-----	BATTALION
(2) Adjusting battery.	When applicable.	BRAVO
(3) Method of fire of adjusting battery.	When different from observer's request.	SALVO LEFT

<i>Element</i>	<i>When announced</i>	<i>Example</i>
(4) Basis for corrections.	When applicable.	USE REGISTRATION POINT 2.
(5) Distribution.	When applicable.	SHEAF, 50 METERS.
(6) Projectile----	When different from observer's request.	SHELL WP
(7) Ammunition lot and charge.	When applicable.	LOT TZ, CHARGE 5.
(8) Fuze-----	When different from observer's request.	FUZE TIME
(9) Number of volleys.	Always in area fire; never in precision fire.	5 VOLLEYS
(10) Range spread or zone.	When different from observer's request.	ONE C APART

<i>Element</i>	<i>When announced</i>	<i>Example</i>
(11) Time of opening.	When different from observer's request.	AT MY COMMAND.
(12) Concentration number.	Always-----	CONCENTRATION ALFA KILO 413.

c. The following considerations affect the elements of the fire order:

- (1) *Batteries to fire.* The decision as to which battery or batteries will fire for effect in a mission depends on—
 - (a) The number of batteries available.
 - (b) The size of the area to be covered and the accuracy of location.
 - (c) The caliber, type, and number of weapons per battery.
 - (d) Whether or not surprise fire is possible.
 - (e) The importance of the target.
 - (f) The relative locations of batteries to each other and to the target.

[illegible]

DA Form 6-16
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 102. Recording the initial fire request.

- (g) Whether the purpose of fire is neutralization, harassment, or interdiction.
 - (h) The battery with the most recent or best corrections in the zone to be covered.
 - (i) The status of ammunition.
 - (j) The policies of the commander.
- (2) *Adjusting battery.* For registration and for missions requiring fires of the battalion, it is usually better to use the midrange battery as the adjusting battery. In a battalion consisting of different caliber weapons the battery having the smallest caliber weapon is normally chosen as the adjusting battery.
- (3) *Method of fire of adjusting battery.* Unless the observer requests a different method of fire, volley fire by the center platoon is used during the adjustment.
- (4) *Basis for corrections.* If the target is within transfer limits of a registration point for which corrections are available, the S3 will specify in his fire order USE REGISTRATION POINT (so-and-so). If the target is within transfer limits of more than one registration point, the registration point nearest the target will give the most accurate corrections if the corrections are current.
- (5) *Distribution.* When the S3 desires or the observer has requested a pattern of bursts other than that obtained by firing a parallel sheaf, the fire order must include a command for distribution. In those rare cases when special corrections are desired, the S3 commands SPECIAL CORRECTIONS followed by a description of the sheaf desired; e.g., SPECIAL CORRECTIONS, CONVERGED SHEAF. When the S3 wishes to adjust only the width of the sheaf by the rapid computation and application of a deflection difference, he indicates that wish by including in the fire order a command indicating the desired width of sheaf; e.g., SHEAF 100 METERS.
- (6) *Projectile.* The projectile or combination of projectiles selected depends on the mission and the nature of the target. If neither the observer's fire request nor the fire order specify the projectile to be fired, shell HE is used.
- (7) *Ammunition lot and charge.*
- (a) There can be an appreciable difference in the ballistic characteristics of different lots of ammunition. Disregard of lot numbers can seriously impair the accuracy of fire. Mixing lots in a single observed fire mission can materially increase the dispersion pattern and can even invalidate an adjustment. Large lots are normally reserved for registrations and subsequent transfers (observed and unobserved). Smaller lots are expended on battery will-adjust missions. Accurate ammunition records, to include a record of lot numbers, must be maintained at section, battery, and battalion levels.
 - (b) For fixed and semifixed ammunition, the ammunition lot number pertains to an assembled projectile-propellant combination. For simplicity, the lot number may be coded; e.g., lot X. Letters at the beginning of the alphabet should not be used to designate lots. This will prevent confusion in the fire order. For separate loading ammunition, when a specific projectile-propellant combination is desired, the lot may be coded as lot XY, with X designating projectile lot and Y designating propellant lot. Segregation and coding of fuzes by lot number is necessary for time fuzes only.
 - (c) The mission, nature of the target and terrain, ammunition available, type of fuze to be used, range, and effects sought govern the selection of the charge to be used. When a target is attacked with low-angle

fire, a charge that will permit firing at elevations between 240 and 460 mils should be selected.

- (d) Each computer will have readily available a list of the registration points and the lot numbers and charges used thereon. If the S3 specifies a basis for corrections in his fire order, he will omit the lot number and charge. Each computer will determine the lot number and charge for his battery by referring to the list mentioned above.
- (e) If a basis for corrections is not specified by the S3 in his fire order, he must designate the charge to be fired (except in high-angle fire) and the lot number. When a will-adjust mission is to be fired by only one battery, the lot number need not be specified by battalion but should be specified by the battery executive officer to avoid firing different lots by the howitzer sections and to implement the battery commander's plans and policies with respect to expenditure of the lots on hand; e.g., consume smallest of the odd lots first.
- (f) A battalion may be composed of different caliber batteries. The lot number and the charge, if announced, would be announced for each battery in this case. For example, BATTALION, ALFA: ALFA, LOT X-RAY, CHARGE 5; BRAVO, LOT X-RAY YANKEE, CHARGE 4; etc.
- (8) *Fuze.* The mission, nature of target and terrain, fuzes available, range, and effects sought govern the selection of the fuze to be used. The omission of fuze in the fire order indicates agreement with the observer's selection of fuze.
- (9) *Number of volleys.* The mission, nature of target, batteries and ammunition available, and pertinent orders from higher headquarters govern the

number of volleys to be fired in fire for effect.

- (10) *Range spread or zone.* The area to be covered, the accuracy of the target location, and the probable error of the weapon should be considered in determining the range spread or zone to be used. Normally, a battalion should not fire with a range spread greater than one C (100 meters) between batteries, because a greater spread will not give uniform coverage of the target area. When a zone is to be fired, the fire order should specify the zone in terms of mils and quadrants; e.g., ZONE 5 MILS, 5 QUADRANTS.
- (11) *Time of opening fire.* The mission, nature of the target, and effect desired govern the selection of time of opening fire, such as TIME ON TARGET (TOT), AT MY COMMAND, WHEN READY, or any specific time according to a prearranged schedule. The omission of a time for opening fire indicates that the batteries would fire when ready unless the observer has requested otherwise.
- (12) *Concentration number.* A number is selected for each concentration from the block of numbers assigned to the battalion (FM 6-20) unless a number has been specified by higher headquarters. The battalion, division artillery, artillery group, corps artillery, or army artillery may assign a number to a concentration. This number may be preceded by a letter(s) prefix to indicate the unit which assigned the number. A list of the numbers will be kept readily available in order to avoid duplication.

d. The standards for those elements of the fire order that have standards are as follows:

Element	Standard
Method of fire of adjusting battery	Center one round
Distribution	Parallel sheaf
Projectile	Shell HE
Fuze	Fuze quick
Range spread or zone	Center range
Time of opening fire	When ready

e. By omitting an element of the initial fire request the observer is, in effect, requesting the standard for that element. For example, by omitting a request for fuze, the observer is requesting fuze quick. When the S3 cannot fulfill the requirements of the initial fire request because of ammunition shortages, policies of the commander, or for other reason, he so specifies in the fire order. For example, the following initial fire request is received in the FDC: COORDINATES 41423617, AZIMUTH 1460, INFANTRY PLATOON IN OPEN, SALVO LEFT, FUZE VT, WILL ADJUST. The S3 decides that fuze time will have to be used in this mission. He issues the following fire order: BATTALION ALFA, USE REGISTRATION POINT 2, FUZE TIME, 4 VOLLEYS, CONCENTRATION ALFA JULIETT 401. Based on this initial fire request and fire order, all of the batteries will fire four volleys at center range in fire for effect; Battery A will conduct the adjustment and will fire the center two pieces, from left to right; shell HE and fuze time will be used throughout the mission; the charge and lot number used on registration point 2 will be fired; and each volley will be fired by the battery when ready.

401. Announcing and Recording the Fire Order

a. The fire order is announced to all personnel in the fire direction center. Each computer, except when actively engaged in another mission, records the fire order on DA Form 6-16, as shown in figure 103.

b. Items 1, 9, and 12 of the fire order (par. 400e), together with any other elements which differ from the initial fire request, are transmitted to the observer. In the example in paragraph 400b, BATTALION, FUZE TIME, 4 VOLLEYS, CONCENTRATION ALFA JULIETT 401 would be sent to the observer.

402. Determining, Recording, and Transmitting Preliminary Fire Command

a. Immediately on receiving the initial fire request and the fire order, computers determine, transmit to the battery, and record all fire commands except those determined from the chart

and graphical equipment. For example, the following initial fire request is received, COORDINATES 43211234, AZIMUTH 1430, VEHICLE PARK, WILL ADJUST; and the following fire order is given, BATTALION, BRAVO, LOT X-RAY YANKEE, CHARGE 5, 4 VOLLEYS, CONCENTRATION ALFA JULIETT 432. By examining the recorded initial fire request and the fire order, the adjusting battery (B) computer determines and records the following on DA Form 6-16 (fig. 104).

- (1) *Battery adjust.* The fire order indicates the battalion is to fire and Battery B is to adjust.
- (2) *Shell HE.* By omission of the type of projectile in both the initial fire request and the fire order, the use of shell HE is implied.
- (3) *Lot XY.* The fire order indicates use of lot XY.
- (4) *Charge 5.* The fire order indicates use of charge 5.
- (5) *Fuze quick.* By omission of fuze in both the initial fire request and the fire order, the use of fuze quick is implied.
- (6) *Center one round.* Volley fire by the center platoon of the adjusting battery was implied by omission of a method of fire in the observer's request and the fire order. Battery B was designated in the fire order to conduct the adjustment. The computer designates only the center two pieces to fire one round during the adjustment.
- (7) *Battery 4 rounds in effect.* The fire order specifies 4 volleys in effect.

b. The procedure in *a* above is the same for the nonadjusting batteries, except for the fire commands which must include DO NOT LOAD; e.g., BATTERY 4 ROUNDS, DO NOT LOAD. Transmission of commands to nonadjusting batteries, together with DO NOT LOAD, permits preparation of the ammunition and laying the pieces in the approximate direction to the target to minimize changes when the command to fire is received.

[illegible]

[illegible]

DA Form 6-16
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 104. Recording the preliminary fire commands.

c. The computer transmits all fire commands to the firing battery in the proper sequence as they are determined.

403. Determining Target Altitude

The vertical control operator determines the altitude of the target by one of four methods:

a. The altitude may have been determined by survey.

b. The fire request may contain the altitude (usually the case when another unit determines the target location).

c. The fire request may locate the target by a shift from a known point. In this case, the vertical control operator applies the vertical shift (zero if none is specified) to the altitude of the known point to determine the target altitude. (The map altitude is disregarded.)

d. The altitude is determined from a map when the observer has located the target by grid coordinates.

404. Determining and Announcing Site

a. The VCO computes site. The vertical interval from battery to target is determined by subtracting the battery altitude from the target altitude; using the vertical interval and the range (to the nearest 10 meters) to the target, the VCO computes the site with the graphical site table.

b. The site for each battery to fire is computed and recorded by the vertical control operator. When each computer desires site, he will request it by saying, for example, SITE ALFA. The VCO will announce the site to each computer as requested by saying, for example, SITE ALFA, PLUS 7. The computer will repeat SITE ALFA, PLUS 7, to the VCO to insure that the correct site has been received.

405. Determining and Recording Fire Commands Based on Chart Data (Using Aluminum Range-Deflection Protractor)

a. The HCO determines and announces the range and deflection. The range-deflection protractor is positioned so that its vertex is against the appropriate battery pin and the arm is

against the target needle. The range is read on the range scale opposite the target needle and is announced to the nearest 10 meters. The deflection is read from the arc at a point opposite the deflection index and is announced to the nearest mil. The HCO will announce this data to each computer by saying, for example, ALFA, RANGE 5020, DEFLECTION 2813.

b. Initial chart data for all batteries are determined and announced by the horizontal control operator. The data for the adjusting battery are announced first. Unit SOP should designate the sequence to be used for nonadjusting batteries.

c. During adjustment, data are determined and announced for the adjusting battery only. When fire-for-effect is requested, data for all batteries are announced.

d. After receiving the chart data, the computer determines and announces the following data:

- (1) *Deflection.* The computer adds to the chart deflection, the deflection correction determined from the deflection correction scale and announces the total as DEFLECTION (so much). The deflection correction remains constant throughout a low angle mission.
- (2) *Time.* The computer determines the fuze setting for time fuze by placing the hairline of the GFT over the chart range and reading the fuze setting under the time gageline. If no time gageline has been constructed, the fuze setting is read under the elevation gageline or under the hairline if no elevation gageline has been constructed. The fuze setting is announced as TIME (so much).
- (3) *Quadrant elevation.* The computer determines the elevation by placing the hairline over the chart range and reading the elevation under the elevation gageline. If no elevation gageline has been constructed, elevation is read under the hairline. He then adds the site, determined by the VCO, to the elevation. If time or VT fuze is to be

fired, the height of burst correction (20/R) is also added. He announces the sum as QUADRANT (so much).

e. The computer records the data announced by the HCO and VCO and the fire commands on the FDC computer's record (DA Form 6-16) (fig. 105).

406. Measuring and Announcing the Angle T

a. Based on the azimuth given in the initial fire request, the HCO determines the size of the angle T to the nearest 10 mils if an adjustment is to be made. This operation is performed after the initial data are read from the chart. The HCO may determine the size of the angle T by measuring or computing it.

b. The size of the angle T, to the nearest 100 mils, is announced to the observer when it is 500 mils or greater. The size of the angle T may be requested by the observer at any time.

407. Procedure to Correct a Misorientation of Target Grid

If the observer sends an azimuth which is in error, the resulting error in orientation of the target grid (DA Form 6-53) should be corrected when it is large enough to cause the observer difficulty in adjusting.

a. In figure 106, the observer's first correction is ADD 400. The chart operator moves the target needle to a point equivalent to 400 meters

[illegible]

DA Form 6-16
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 105. Recording chart data and fire commands.

up the OT line, and a round is fired with the data obtained.

b. The observer's next correction of RIGHT 200, REPEAT RANGE indicates that the reported azimuth is in error. The chart operator moves the target needle to a point equivalent to 200 meters right of its last location and notes the position of the constructed line shot.

c. While a round is being fired with these data, the chart operator rotates the target grid until the arrow is parallel to the line formed by the previous line shot and the constructed line shot. The target grid is now oriented correctly. When the next observer correction is received, the target needle is moved from the chart location of the last round fired.

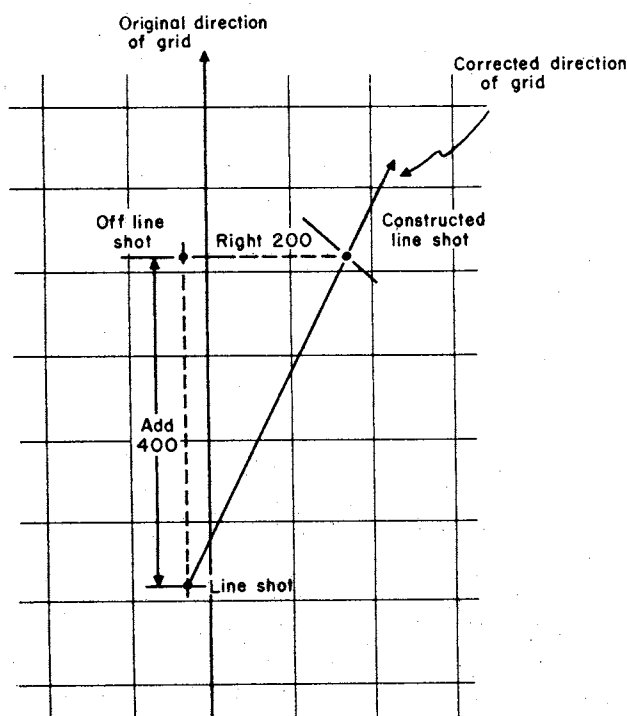


Figure 106. Correcting a misorientation of the target grid.

408. Procedure During Fire for Effect

a. When fire-for-effect is requested, the HCO determines and announces chart data for all batteries that are to fire.

b. The adjusting battery computer announces to the nonadjusting battery computers any change in fuze and the total correction to height of burst made during adjustment. For example, in a fuze time mission, the observer's

total height of burst correction during adjustment was down 10 meters, the adjusting battery computer would announce CORRECTIONS, DOWN 10. If no changes in fuze or corrections to height of burst were made, the adjusting battery computer would announce CORRECTIONS, NONE.

c. All computers convert the chart data to firing data. Fire commands, including the method of fire specified in the fire order and the firing data, are announced to the firing battery.

d. When a range spread (1 C apart or $\frac{1}{2}$ C apart) has been directed in the fire order, the batteries will fire at different ranges. All chart data will be determined at center range. Normally, the adjusting battery computer will determine firing data based on the chart data announced by the horizontal control operator. One nonadjusting battery will fire beyond center range and the other will fire short of center range. The nonadjusting battery computers will add or subtract 50 meters ($\frac{1}{2}$ C) or 100 meters (1 C) whichever is appropriate to the chart range announced by the horizontal control operator. The nonadjusting battery computers determine firing data based on the modified chart range and the announced chart deflection. In a two-battery battalion, a procedure should be established so that all personnel, including observers, will know whether the nonadjusting battery is to fire beyond, or short of, the adjusting battery.

e. Each battery fires for effect as soon as it is ready, except when delayed fire for effect is desired. Delayed fire for effect may be used to advantage for any target consisting of personnel who must return to complete a specific job. Also, it may be used for firing on an adjusting point where a target must appear; for example, engineer construction, such as bridges or crossroads frequently used by vehicles or personnel. Time on target procedures (par. 415) can be used in these situations.

f. When the first volley is on the way, the firing battery reports to the FDC, ON THE WAY. Firing for effect is transmitted to the observer, who reads back FIRING FOR EFFECT, OVER. When the last battery to fire has reported ROUNDS COMPLETE, a message is transmitted from the battalion FDC to

the observer as BATTALION ROUNDS COMPLETE and he acknowledges with BATTALION ROUNDS COMPLETE, WAIT.

g. When the observer sends END OF MISSION (EM) and the results of the mission, the message is read back and recorded at the battalion fire direction center. The mission is ended by sending OUT as the terminating word in the read-back.

h. The battery computers record the observer's report and, on completion of the mission, announce to the battery END OF MISSION, CONCENTRATION (so-and-so). END OF MISSION, CONCENTRATION (so-and-so) is entered on the Recorder's Sheet (DA Form 6-17) for future reference. At the completion of a mission, the battery computers, using DA Form 6-16, and the recorder, using DA Form 6-17, complete the ammunition record.

409. Multiple Fire Missions

a. Two fire missions can be processed in the battalion FDC simultaneously. All fire requests received at the FDC are acknowledged and recorded. When a battalion fire mission is in process and another mission is received, the mission is recorded by a second radiotelephone operator and is plotted by the VCO in order for the S3 to examine it and reach a decision to fire. Since only two fire missions (one per chart) can be conveniently processed concurrently, the S3 must make a decision when two or more requests are in the fire direction center. The S3 may stop firing a mission in order to attack a more important target; he may take the mission and notify the observer that there will be a delay; he may call on attached or reinforcing battalions; he may request fire through higher headquarters; he may, if the target is suitable for attack by a battery, designate the VCO and one battery computer to process the mission or assign the mission to a battery to be processed; or he may decide the target is not sufficiently important to be attacked and treat the request only as intelligence information and so inform the observer.

b. If a battalion will-adjust mission is in process and a fire request is received which re-

quires the use of only one battery, the S3 may assign the new mission to one of the nonadjusting batteries at once. The S3 would order the selected battery SUSPEND ON CONCENTRATION ALFA BRAVO 205, FIRE MISSION. The fire request, already recorded, would be repeated to the selected battery computer. A fire order for the mission would be announced. END OF MISSION, followed by the new fire commands, would be announced by the computer to the firing battery. If the battery should complete this mission before the mission of concentration ALFA BRAVO 205 is in fire for effect status, the S3 might order this battery to RESUME ON CONCENTRATION ALFA BRAVO 205.

410. Registration

Normally, the S3 supervises registrations. Registrations may be conducted by the battery when directed by battalion. To insure uniform application of corrections, the officer who conducts the registration immediately transmits the correction to all batteries and the battalion fire direction center. The corrections are not applied until the S3 so directs. Computers maintain a record of current GFT settings and deflection corrections.

411. Procedure Using Time Fire

A 20 meter height of burst is a mean height suitable for light, medium, heavy, and very heavy artillery and will produce effective results without an excessive number of graze or high air bursts owing to the vertical probable error. When a time fuze is being used and a fire command including DO NOT LOAD is received at the firing battery, the fuze setter is set at the time announced but the fuze is not cut until a command to fire the round has been received. This procedure will preclude the setting of the fuze more than once if a different fuze setting is required when the final time is announced.

a. When time fuze is ordered, an angle of site based on a vertical interval of 20 meters and the GT range must be computed and added to the site determined for the ground location. Determination of this angle of site is simplified

by using the $100/R$ scale on the GFT or the GFT fan. The value of $100/R$ is a function of range and indicates the number of mils required to move the burst 100 meters in height or deflection. Since only 20 meters height of burst is desired in time fire, only 0.2, or one-fifth of the figure obtained from the $100/R$ scale is required. For example, when the range is 6,000 meters, the $100/R$ factor is 17 mils. One-fifth, or 0.2 of 17 is 3.4 mils. Thus, 3 mils would be added to the site to achieve a 20-meter height of burst in this instance. Complementary angle of site for the increased vertical interval of 20 meters is insignificant and is ignored.

b. The computer determines the angle of site for height of burst and combines that angle of site with the site announced by the VCO and the elevation to determine the quadrant elevation to be announced to the guns.

c. When a subsequent height of burst correction is given by the observer, the computer uses the $100/R$ factor (determined at initial chart range) to determine the site correction. The site correction is applied to the previous site. For example, the observer gives a command UP 40. The $100/R$ factor, 17 mils, is multiplied by 0.4, with a result of plus 6.8, or plus 7, mils. The previous site (including $20/R$) is plus 8. The new site is plus 15.

d. Deflection, time, and elevation are determined in the manner described in paragraph 405d.

412. Procedure Using VT Fuze

a. When VT fuze is used, as with time fuze, an additional angle of site, $20/R$, must be added to the site determined for the ground location. Application of this additional angle of site compensates for the foreshortened range that would result if the fuze functioned on a trajectory determined for a ground impact location (fig. 107). The height of burst obtained with VT fuzes varies in different types of terrain and with different angles of fall, resulting in a varying range effect. If an unsatisfactory range results, the observer must make a range correction to bring the effect to the desired location. For future missions in the same area, a similar correction may be applied for fire for effect with VT fuze. In high-angle fire, there is no need to compensate for the shortened range, since the descending branch of the trajectory is nearly vertical.

b. The height of burst correction added to the site is determined in the same manner as described in paragraph 411a.

c. When VT fuze is to be used in fire for effect, adjustment is made with fuze quick in order to facilitate sensings. To expedite delivery of fire for effect, the fire commands to the adjusting battery will state, as a part of the method of fire, the number of VT fuzed rounds to be used in fire for effect. Typical fire commands for an adjusting battery would be BATTERY ADJUST, SHELL HE, LOT X

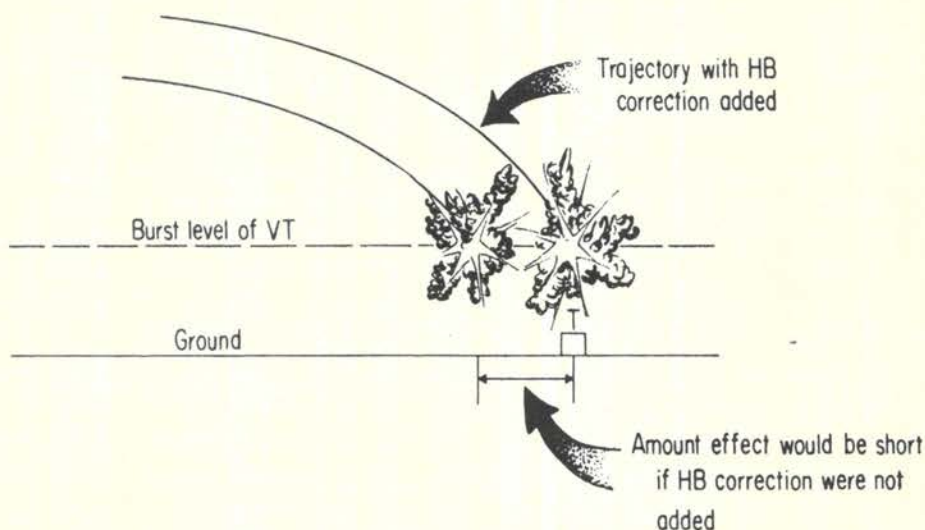


Figure 107. Result of a height of burst correction to VT fuze effect.

RAY, CHARGE 5, FUZE QUICK, CENTER ONE ROUND, BATTERY 3 ROUNDS VT IN EFFECT, DEFLECTION 2759, QUADRANT 352.

d. The computer computes the height of burst correction (using 100/R at initial chart range) and applies it as a part of site on entering fire for effect. Nonadjusting battery computers will determine the height of burst correction and apply it in the initial commands, which are sent together with DO NOT LOAD as a part of the method of fire.

e. When VT fuzes are used and the source of data is tabular firing tables or graphical equipment which includes time of flight data, a fuze setting corresponding to the time of flight to the target is set on the fuze ring. The time of flight to the target is that corresponding to the elevation to be fired. If the time of flight to the target is not a whole number, the next lower whole number is set on the fuze ring. For example, if the time of flight corresponding to the elevation to be fired is 24.2 seconds, the fuze setting for the VT fuze is 24 seconds. This is announced as TIME 24.0.

f. When VT fuzes are used and the source of data is graphical equipment which does not include time of flight data, the fuze setting for the VT fuze is obtained by subtracting 1 second from the fuze setting for MTSQ (mechanical time superquick) fuzes as read under the *elevation* gageline. If the result is not a whole number, it is rounded to the next *lower* whole second. For example, if the MTSQ fuze setting read under the elevation gageline is 26.4 seconds, the fuze setting for the VT fuze is announced as TIME 25.0.

g. Since fuze quick is used in adjustment, the fire commands for time is announced with fire for effect data for the adjusting battery. A fuze setting command is included in the initial commands for nonadjusting batteries. If the observer reports that VT fuzes are bursting on impact, the fuze setting for the VT fuze is decreased 1 second.

413. Procedure for Mission by Air Observer

a. The air observer, with no fixed location, normally omits azimuth in his initial fire re-

quest. He will usually adjust with respect to the gun target line. If coordinates are used initially to locate the target, the chart operators plot the coordinates and determine chart data. The target grid is then centered on this plot and oriented with the 0-3200 line parallel to the arm of the range-deflection protractor. The vertex of the range-deflection protractor is at the *adjusting battery* pin and the edge is against the plotting needle. The observer's first subsequent fire request is plotted with the target grid oriented as described above, and the chart data is determined. The target grid need not be reoriented after subsequent fire requests unless there has been a change of 200 mills or more in direction of fire during the mission. If necessary, the target grid is reoriented by rotating (using the target needle location as a pivot point) until the 0-3200 line of the target grid is again parallel to the arm of the range-deflection protractor.

b. To plot an initial target location as a shift from a registration (known) point, the chart operator must center the target grid over the registration point and orient the 0-3200 line parallel to the center battery-registration point line. The observer's shift is plotted, and chart data are determined. The target grid is then reoriented parallel to the *adjusting battery*-target line. Thereafter, the target grid need not be reoriented during the mission unless the direction of fire changes more than 200 mills.

c. The target grid may also be oriented with respect to a reference line, such as a railroad, or the azimuth announced by the observer. In this case, the target grid is centered over a pre-designated point, and the 0-3200 line is oriented parallel to the reference line. The observer's subsequent fire requests are with respect to the reference line; so the target grid needs no re-orientation.

414. Procedure When Ground Observer Is Moving Rapidly

a. Occasionally a ground observer, especially one mounted in a tank, finds it necessary to adjust with respect to the gun-target line. The

fire direction procedures involved are the same as those prescribed for the air observer (para. 413 a and b).

b. When an observer is moving rapidly while adjusting on the OT line, his OT azimuth may change considerably during a mission. If the observer does not change the azimuth in a subsequent fire request, the FDC will change it, if necessary, using the procedure described in paragraph 407.

415. Procedure for Time on Target Missions

a. Time on target (TOT) is a special technique of firing the pieces of several units so that the projectiles of all the units firing arrive at the target at the same time. This technique gains the full value of the element of surprise. The time on target may be set by giving the time of day that fire is to be delivered. For example, the order may state TIME ON TARGET IS 0915 HOURS ----- TIME IS 0905: ----- NOW.

Time on target may also be ordered as TIME ON TARGET IS (so many) MINUTES FROM ----- NOW! Generally, 10 minutes in the foregoing orders will give all units sufficient time.

b. The target is plotted and firing data and fire commands are determined as usual except for the method of fire. The battalion S3 will include AT MY COMMAND, TIME ON TARGET, in his fire order for time on target missions. The fire command initially transmitted to the firing battery will include DO NOT LOAD. At the appropriate time, the method of fire is changed to include AT MY COMMAND, TIME ON TARGET (so many) MINUTES FROM ----- NOW. Each battery executive officer coordinates the time of loading so that the rounds do not remain in the chambers longer than 30 seconds prior to firing and reports when the battery is ready. The time at which a battery will load can be determined by subtracting the time of flight plus 30 seconds from the time on target. The time of flight should be sent to the executive officer if the fire commands do not include a fuze setting.

c. To coordinate the firing of all batteries, the battalion S3 starts a time count at the ap-

propriate time, counting by seconds starting approximately 10 seconds before the battery with the longest time of flight must fire. Each battery is given the command FIRE when the battalion S3 announces the time in his counting which corresponds to the time of flight for the battery plus 2 seconds. This 2 seconds is added to the time of flight in order to allow for the time lag between the announced count and the actual firing of the pieces.

d. For example, the following message has been received from a division artillery fire direction center:

THIS IS (CALL SIGN), FIRE MISSION,
FIRE 2 VOLLEYS, SHELL HE, FUZE
VT, COORDINATES 6454231420, ALTI-
TITUDE 420 METERS, CENTER RANGE,
CONCENTRATION ALFA FOXTROT
101, TIME ON TARGET, TIME ON TAR-
GET WILL BE 10 MINUTES FROM
----- NOW.

The battalion S3 starts his stop watch at the command NOW and begins his count by saying, when appropriate, "Time on target is six zero seconds from NOW ----- five zero ----- four zero ----- three zero, 29, 28, 27, 26," etc., until all batteries have fired. The computer of a battery which has a time flight of 13 seconds for this target would command FIRE at the announced count of 15.

416. Replotting Targets

Only those targets requested for replot by the observer or directed by the S3 will be re-plotted. Replot data consist of the coordinates, altitude, fuze, and concentration number. Fire for effect chart data, particularly altitude (site), are not always precise. Within the battalion, fire for effect data, if used again without changing ammunition lots or without an appreciable change in weather, will usually cause effective fire to fall on the target. However, if target locations are sent outside the battalion or if targets are refired with different corrections for nonstandard conditions, the target replot coordinates and altitude must indicate the actual ground location as nearly as possible. The more accurately corrections are known and are applied, the more accurate will the replot

data be to the actual ground location. The procedures for determining replot data differ with the fuze action used in fire for effect.

a. Point Detonating Fuze.

- (1) During the adjustment of point detonating fuze, the observer seldom corrects for difference in altitude. Therefore, the site fired is often not the true site to the target. Any error in site will be reflected as a range error on the firing chart. If the true site to the target is computed and then subtracted from the quadrant elevation used in fire for effect, the resulting elevation can be used to determine the range to the target. True site is determined by successive approximations using a grid sheet and map. Since known deflection corrections are applied throughout each mission, the fire for effect *chart* deflection will serve as the replot deflection. The difference between the deflection correction for the initial target location (that used) and the deflection correction for the fire for effect location is small and may be ignored.
- (2) The adjusting battery computer announces the deflection and range for the initial replot to the horizontal control operator. The replot deflection is the final chart deflection announced by the horizontal control operator. The replot range is the range read under the hairline when the elevation gage-line is placed over the elevation fired (quadrant elevation minus site). The HCO polar plots the target from the adjusting battery pin at the deflection and range announced by the computer. He then announces the coordinates to the VCO. The VCO then determines the map altitude of the replotted target. Using this altitude and the range at which the target is now plotted, the VCO computes a new site, which he announces to the computer.
- (3) If the site, announced by the VCO, does not agree within 1 mil of the site

fired, it is subtracted from the quadrant elevation fired and the resulting elevation is used to determine a new replot range. The replot deflection remains the same. The HCO polar plots this new data and announces the coordinates to the VCO. The VCO then determines the map altitude of the replotted target. This procedure, commonly called successive approximation, is repeated until the site announced by the VCO agrees within 1 mil of the site previously computed.

- (4) When the site announced by the VCO agrees with, or within 1 mil of, the last site computed, the computer will use the final site and compute an adjusted elevation. The computer announces the final replot range based on this adjusted elevation; the HCO polar plots the target at the deflection and range announced by the computer. He then announces the replot coordinates to the computer. The VCO announces the altitude used to determine the final site. The computer records the replot coordinates and altitude, fuze used in fire for effect, and concentration number on the computer's record.
- (5) *Examples:* Battery A, 155-mm How (FT 155-Q-3), altitude of battery 405 meters, GFT setting: GFT A, Charge 4, Lot ZT, Range 5240, Elevation 350.

(a) Mission number 1.

Fire for effect data:

Charge 4
Fuze quick
Deflection fired 2414
Chart deflection 2406
Quadrant 373

Site initially computed ----- -11 mils

Fire for effect elevation 373-
(-) 11 ----- 384 mils

Computer to HCO:

Replot deflection (fire for effect
chart deflection) ----- 2406 mils

Replot range (range corresponding
to elevation 384) ----- 5600 meters

The HCO polar plots the target at deflection 2406 and range 5600. He reads and announces

the coordinates, 43713421, to the VCO. The VCO plots the coordinates and determines the altitude of the point to be—	366 meters	site (—9 miles) Replot Altitude 363 meters. DATA FOR RE-PLOT: Coordinates 43733416, Altitude 363 meters, Fuze quick, Concentration number AC601.	
The VCO computes the first apparent site and announces it to the computer. (Vertical interval —39 meters, range 5600) -----	—8 miles	(b) <i>Mission number 2.</i>	
Computer determines the first apparent elevation (373— (—) 8) -----	381 miles	Fire for effect data:	
Computer to HCO:		Charge 4	
Replot deflection -----	2406 miles	Fuze quick	
Replot range (range corresponding to elevation 381) -----	5560 meters	Deflection fired 2392	
The HCO polar plots using these data and announces coordinates 43743417 to the VCO. The VCO plots the coordinates and determines the altitude of this points to be— -----	363 meters	Chart deflection 2387	
The VCO computes the second apparent site and announces it to the computer (Vertical interval —42 meters, range 5560) -----	—9 miles	Quadrant 277	
Site agrees within 1 mil of last site computed. Computer determines the adjusted elevation (373— (—) 9) -----	382 miles	Site initially computed -----	+5 miles
Computer to HCO:		Fire for effect elevation (277— (+) 5) -----	272 miles
Replot deflection -----	2406 miles	Computer to HCO:	
Replot range (range corresponding to elevation 282) -----	5570 meters	Replot deflection (fire for effect chart deflection) -----	2387 miles
The HCO polar plots using these data and announces to the computer. Replot coordinates 43733416. The VCO announces altitude used to determine final		Replot range (range corresponding to elevation 272) -----	4320 meters
		The HCO polar plots the target at deflection 2387 and range 4320. He reads and announces the coordinates, 41723614, to the VCO. The VCO plots the coordinates and determines the altitude of the point to be—	425 meters
		The VCO computes the first apparent site and announces it to the computer (Vertical interval +20 meters, range 4320) -----	+5 miles
		Site agrees with the computed site. DATA FOR REPLOT: Coordinates 41733614, Altitude 425 meters, Fuze quick, Concentration number AC605.	

b. *Fuze VT.* Replot of targets attacked with VT fuze is accomplished as described in *a* above for point detonating fuze, except that the quadrant elevation used in the successive approximation is the quadrant elevation used in fire for effect minus the height of burst correction (20/R) (in mils) that was applied.

c. *Fuze Time.*

- (1) To replot a target in a fuze time mission, the site derived from firing minus the 20/R computed at fire for effect range is accepted as correct, and the altitude determined from this site and fire for effect range is the altitude assigned to the target.
- (2) The coordinates of the final target needle locations are announced by the HCO as the replot coordinates. The site fired (minus 20/R computed at fire for effect range) is announced to the VCO by the computer. The VCO computes the vertical interval between the adjusting battery and the target, using the site announced and the fire for effect range. The vertical interval is added algebraically to the altitude of the adjusting battery to determine the altitude of the target.

417. Report of Firing to Battalion S2

The chief computer will report all missions fired to the battalion S2 as soon after the end of the mission as possible. For example, "Bat-

talion fired 3 volleys on 100 infantry digging in at 60053687, estimate 20 casualties, remainder withdrawing."

418. Records

a. The battery computers will maintain a temporary file of FDC Computer's Records (DA Form 6-16) for possible future reference.

b. A blackboard or sheet of acetate may be used for posting current GFT settings and registration and met data. It also may be used for posting any other information of immediate use of the fire direction personnel. A record of registration and met data as well as velocity errors developed with specific ammunition lots should be kept for reference.

c. The battalion chief computer and the battery computers should maintain a temporary file of records of precision fire.

d. The computer maintains a temporary file of data sheets for all prearranged fires sent to the battery.

e. The battery computers will maintain a current record of all ammunition present in the battery. If necessary, the computer's record may be supplemented in order to make the record complete.

f. The battalion chief computer will keep a current master ammunition record that will be a consolidation of the ammunition records of the battery computers plus the amount of ammunition in the battalion train.

Section IV. BATTERY FIRE DIRECTION

419. General

a. The battery executive officer is responsible for the control of the firing battery. This responsibility extends to the production of firing data and fire commands when the battery fire direction personnel are processing a mission. The executive officer exercises control of the firing battery from any position in the firing battery area that he chooses to occupy.

b. The **battery fire direction center** is the installation within the firing battery through which the executive officer controls his howitzers (guns). The **battery fire direction center** is manned by personnel assigned to firing battery headquarters.

c. A battery, in a battalion that normally exercises technical fire direction, will determine fire commands only when—

(1) Operating independently.

(2) Directed to do so by the S3.

d. One or two firing charts (the number is left to the discretion of the commander) are maintained at the battery. If only one chart is maintained, it should be a **grid sheet supplemented by a 1:50,000 map**.

420. Procedures at the Battery When the Battalion is Determining Fire Commands

a. When fire commands are being produced at the battalion FDC, the commands are transmitted to the **battery fire direction center** by the computer at battalion fire direction center. The executive officer is responsible that the fire commands are received, recorded, read back, and relayed to the pieces. Considering the state of

training of his unit, the executive officer must organize his personnel so that fire commands are relayed to the pieces rapidly and accurately. Fire commands are usually received and read back by the computer (at the battery) and are relayed to the pieces and recorded by the recorder. The executive officer (or assistant executive officer or chief of firing battery) must supervise the operations of the computer and recorder. The executive officer himself may transmit the fire commands to the pieces and may do so from any position in the firing battery area that affords him the best control of firing battery operations.

b. During lulls in firing, the battery chart operator(s) and computer receive from the battalion FDC data for the construction of the firing chart and current registration and met data. GFT settings and deflection correction scales are kept current so that the battery can determine fire commands when required.

421. Procedures When the Battery Is Producing Fire Commands

When the battery is required to produce fire commands, appropriate personnel of the firing battery headquarters constitute the FDC and assume the functions of their battalion counterparts; i.e., the executive officer (or whoever is in charge of the firing battery at the time) assumes the duties of the S3, the battery computer those of the computer in battalion FDC, etc. The computer or the recorder may be used to transmit the fire commands to the pieces.

Section V. COMMUNICATIONS

422. General

a. To provide the communications necessary for fire direction, separate radio and wire systems are installed. These systems should parallel each other so far as possible to provide an alternate means of communication if either system fails. The radio and wire systems can readily be adapted to units regardless of caliber or mission. All FDC personnel should be trained in both communication and gunnery techniques. Neither wire nor radio is considered the primary means of communication.

Highest priority must be given to installing the wire lines between the battalion FDC and the **battery fire direction centers** in the firing batteries. The presence of both types of communication permits a selection of the best means to meet any situation. For detailed instructions pertaining to wire and radio communications, see **FM 6-10**.

b. Maximum use will be made of fire direction personnel to set up the communications within the fire direction center. For example, wire personnel will normally lay wire to a terminal near the fire

direction center. FDC personnel are responsible for the communications from the terminal to and throughout the fire direction center. Radio operators will remote the radios. The switchboard operator will conduct the normal wire checks for those lines terminating in the switchboard.

423. Radio (Rescinded)

424. Wire

The extent of the wire system installed depends on the length of time a position is occupied.

- a. If a battalion position is occupied for a

short period of time, lack of time may preclude developing the wire system beyond installing the fire direction lines to the batteries. In this case, radio will carry traffic to liaison officers and forward observers.

b. If a battalion position is occupied for a sufficient length of time, a complete wire system is installed. The installation of wire is started on completion of reconnaissance. The system is expanded and improved until the unit displaces from the position. Wire circuits parallel the radio circuits. As the wire system improves, radio traffic is reduced.

Section VI. SAMPLE MISSIONS

425. One Battery, Fuze Time

a. *General.* An 8-inch howitzer battalion is attached to corps artillery. The battalion has established OP's and a registration has been conducted. The GFT setting derived from the registration is GFT B: Charge 5, lot XY, range 6900, elevation 300, time 22.3. Wire lines to the OP's have not been completed.

b. *Procedures During Mission* (fig. 108).

FO radiotelephone operator.	CIVIL 9, THIS IS CIVIL 26, FIRE MISSION, OVER.
FDC radiotelephone operator (to FDC personnel).	FIRE MISSION.
FDC radiotelephone operator.	CIVIL 26, THIS IS CIVIL 9, SEND YOUR MISSION OVER.
FO radiotelephone operator.	COORDINATES 983642, OVER.
FDC radiotelephone operator.	COORDINATES 983642, OVER.
FO radiotelephone operator.	AZIMUTH 2140, OVER.
FDC radiotelephone operator.	AZIMUTH 2140, OVER.
FO radiotelephone operator.	INFANTRY WEAPONS COMPANY DIGGING IN, FUZE TIME, WILL ADJUST, OVER.
FDC radiotelephone operator.	INFANTRY WEAPONS COMPANY DIGGING IN, FUZE TIME, WILL ADJUST, WAIT.

The chart operators plot the target. The location is checked against no-fire lines and the location of friendly troops. The S3 decides how to attack the target and issues his fire order.

S3-----	49, LOT XY, CHARGE 5, 5 VOLLEYS, CONCENTRATION CHARLIE DELTA 501.
FDC radiotelephone operator.	49, 5 VOLLEYS, CONCENTRATION CHARLIE DELTA 501, OVER.
FO radiotelephone operator.	49, 5 VOLLEYS, CONCENTRATION CHARLIE DELTA 501, OVER.
B computer (to battery).	BATTERY ADJUST, SHELL HE, CHARGE 5, LOT XY, FUZE TIME, CENTER 1 ROUND, BATTERY 5 ROUNDS IN EFFECT.
B telephone operator.	BATTERY ADJUST, SHELL HE, CHARGE 5, LOT XY, FUZE TIME, CENTER 1 ROUND, BATTERY 5 ROUNDS IN EFFECT.
HCO-----	RANGE 7240.
B computer-----	RANGE 7240.
HCO-----	DEFLECTION 2429.
B computer-----	DEFLECTION 2429.
B computer determines	and applies deflection correction, L1.
B computer (to battery).	DEFLECTION 2430, TIME 23.6.
B telephone operator.	DEFLECTION 2430, TIME 23.6.
B computer (to VCO)	SITE BRAVO?
VCO-----	SITE BRAVO, PLUS 3.
B computer-----	SITE BRAVO, PLUS 3.
B computer determines	20/R to be +3 (0.2×14) and adds elevation, site, and 20/R.
B computer (to battery).	QUADRANT 326.
B telephone operator.	QUADRANT 326 ... ON THE WAY.
B computer-----	ON THE WAY.

FDC radiotelephone operator. ON THE WAY, OVER.
FO radiotelephone operator. ON THE WAY, WAIT . . . UP 40, DROP 200, OVER.
FDC radiotelephone operator. UP 40, DROP 200, WAIT.
HCO----- RANGE 7050.
B computer----- RANGE 7050.
HCO----- DEFLECTION 2419.
B computer----- DEFLECTION 2419.
B computer (to battery). DEFLECTION 2420, TIME 22.9.
B telephone operator--- DEFLECTION 2420, TIME 22.9.
B computer determines height of burst correction to be +6 (0.4×14).
B computer----- QUADRANT 321.
B telephone operator--- QUADRANT 321 . . . ON THE WAY.
B computer----- ON THE WAY.
FDC radiotelephone operator. ON THE WAY, OVER.
FO radiotelephone operator. ON THE WAY, WAIT . . . RIGHT 30, DOWN 10, ADD 100, OVER.
FDC radiotelephone operator. RIGHT 30, DOWN 10, ADD 100, WAIT.
HCO----- RANGE 7140.
B computer----- RANGE 7140.
HCO----- DEFLECTION 2420.
B computer----- DEFLECTION 2420.
B computer (to battery). DEFLECTION 2421, TIME 23.2.
B telephone operator--- DEFLECTION 2421, TIME 23.2.
B computer determines height of burst correction to be -1 (0.1×14).
B computer (to battery). QUADRANT 325.
B telephone operator--- QUADRANT 325 . . . ON THE WAY.
B computer----- ON THE WAY.
FDC radiotelephone operator. ON THE WAY, OVER.
FO radiotelephone operator. ON THE WAY, WAIT . . . LEFT 10, DROP 50, FIRE FOR EFFECT, OVER.
FDC radiotelephone operator. LEFT 10, DROP 50, FIRE FOR EFFECT, WAIT.
B computer (to battery). BATTERY 5 ROUNDS.
B telephone operator--- BATTERY 5 ROUNDS.
HCO----- RANGE 7090.
B computer----- RANGE 7090.
HCO----- DEFLECTION 2419.
B computer----- DEFLECTION 2419.
B computer (to battery). DEFLECTION 2420, TIME 23.0, QUADRANT 322.

B telephone operator--- DEFLECTION 2420, TIME 23.0, QUADRANT 322 . . . ON THE WAY.
B computer----- FIRING FOR EFFECT.
FDC radiotelephone operator. FIRING FOR EFFECT, OVER.
FO radiotelephone operator. FIRING FOR EFFECT, OVER.
B telephone operator--- ROUNDS COMPLETE.
B computer----- ROUNDS COMPLETE.
FDC radiotelephone operator. ROUNDS COMPLETE, OVER.
FO radiotelephone operator. ROUNDS COMPLETE, WAIT. . . . END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OVER.
FDC radiotelephone operator. END OF MISSION, ESTIMATE 25 CASUALTIES, REMAINDER DISPERSED, OUT.
B computer (to battery). END OF MISSION, CONCENTRATION CHARLIE DELTA 501.
B telephone operator--- END OF MISSION, CONCENTRATION CHARLIE DELTA 501.

426. Common Errors and Malpractices in the Fire Direction Center

a. The formation of proper habits in training and the use of independent checks are the means of eliminating the common errors and malpractices that occur in the fire direction center.

b. Common errors and malpractices in plotting are—

- (1) Using improper scale of the coordinate square.
- (2) Using yard scale instead of the meter scale.
- (3) Plotting the coordinates from the wrong grid line in the wrong direction, when the firing chart is so placed that north is toward the plotter.
- (4) Putting the center of the protractor over the wrong point.
- (5) Reading azimuths 1,600 or 3,200 mils in error.

c. Common errors and malpractices pertaining to the range-deflection protractor, the GFT Fan, and the GFT are—

- (1) Failing to properly seat the cursor on its ballistic scale or against the target needle (GFT fan).

FDC COMPUTER'S RECORD (FM 6-40)													
Battery B		Time mission Received 1025		Completed 1038		Date 27 MAR 64		Concentration number CD 501					
Fire mission 26 FM COORD. 983642, AZ 2140 INF WPN CO DIGGING IN F2 T1, WA				Correction L1		Deflection 2429		INITIAL FIRE COMMANDS					
				Range 7240 EL 320		Site SITE +3 20/R +3 326		BTRY Adjust, Sp Instr					
Fire order:		Unit(s) to fire B		Sh HE		Lot XY							
Mf		Basis for corr		Chg 5		Fz T1							
		Distr		Mf C ① BTRY ⑤		in eff							
Sh		Lot XY		Df 2430		Time 23.6							
Fz		vol(s) 5		QE 326		Ammo Exp ②							
Rg spread		Time		100/R 14									
Conc nr CD 501													
Observer Corrections			Subsequent fire commands										
Dev	Height	Rg	Fz, MF	Corr	Chort df	Piece df	Rg	HB Corr	Si (+6)	Ti	EI	QE	Ammo exp
	U40	-200		L1	2419	2420	7050	+6	+12	22.9	309	321	④
R30	D10	+100			2420	2421	7140	-1	+11	23.2	314	325	⑥
L10		-50	F2	BTRY ⑤	2419	2420	7090			23.0	311	322	②⑥
EOM - EST. 25 CASUALTIES, REMAINDER DISPERSED													
Data for replot													
Coordinates			Altitude			Fuze			Conc nr				
Ammunition													
Type	HE (LOT X)	HE (LOT Z)	PROP (LOT W)	PROP (LOT Y)	M557	M520	M514						
On hand	287	450	450	287	350	337	96						
Received													
Total													
Expended	26			26		26							
Remaining	261	450	450	261	350	311	96						

DA Form 6-16
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 108. Completed computer's record, fuze time mission.

- (2) Reading wrong elevation or time gage-line when more than one line is placed on a cursor.
- (3) Failing to seat the vertex of the protractor firmly against the pin in the battery position when data are being determined or against the pin in an OP or radar position for polar plotting.
- (4) Reading the data on the GFT from a position other than directly above the index and scale, thus introducing parallax errors.
- (5) Reading deflections from the temporary deflection index rather than from the deflection index or reading deflections from the deflection index of the wrong battery.
- (6) Misreading of deflection.
- (7) Reading deflection from the wrong deflection scale; for example, red numbers for blue numbers.

- (8) Using the ballistic scale for the wrong charge (GFT or GFT Fan).
- (9) Reading drift instead of fork (F) or vice versa.

d. Common errors and malpractices with the target grid are—

- (1) Miscounting in increments of 100 meters in plotting shifts on the grid.
- (2) Failing to orient the target grid properly by using the azimuth scale, which is graduated in a counterclockwise direction.
- (3) Failing to label or construct the azimuth index correctly. This error is especially common when direction of fire is other than north.
- (4) Reversing observer's target location; for example, plotting FROM REGISTRATION POINT, RIGHT 500 as 500 meters left (or over, or short) of the registration point.

CHAPTER 24

FDC PROCEDURES FOR HIGH-ANGLE FIRE

427. General

a. Fire delivered at elevations in excess of the elevation corresponding to the maximum range for each charge is called high-angle fire. Most howitzers are capable of attacking targets effectively with high-angle fire. High velocity weapons (guns) are not normally used for high-angle fire because high muzzle velocity results in high maximum ordinate, long time of flight, and large probable error. High-angle fire is used to fire into or out of deep defilade. The observer may request or the S3 may order high-angle fire.

b. High-angle fire involves high maximum ordinates and correspondingly long time of flight. Small changes in range cause relatively large changes in maximum ordinate and time of flight. To assist an observer in identifying his rounds, fire direction center will notify the observer ON THE WAY and may give the time of flight. Time of flight must always be given to an air observer. The time of flight may be coded to provide security for the battery location. The warning SPLASH will be given 5 seconds prior to impact.

c. The principal difference between low-angle fire and high-angle fire is that, in high-angle fire, an *increase* in elevation will cause a *decrease* in range.

428. Fire Order

When high-angle fire is to be used, the S3 will omit the charge from the fire order and substitute the words "high-angle." If appropriate, the command INCLUDE SITE follows HIGH-ANGLE (para 433a).

429. Fire Commands

a. Fire commands for high-angle fire must include the command HIGH-ANGLE to alert

the gun crews that a high-angle mission is to be fired. This command follows the ammunition lot number. All other commands for a precision mission and for the adjusting battery for an area mission are the same as for low-angle fire. The charge, which may change during the adjustment, the fuze setting (CVT fuzes), and the quadrant elevation, which cannot be used until the piece is to be loaded, are omitted in the initial fire commands to the nonadjusting batteries. For example—

<i>Adjusting battery</i>	<i>Non adjusting battery</i>
BATTERY ADJUST	BATTERY ADJUST
SHELL HE	SHELL HE
LOT X	LOT X
HIGH-ANGLE, CHARGE	HIGH-ANGLE (charge is omitted).
4.	
FUZE QUICK	FUZE QUICK
CENTER 1 ROUND,	BATTERY 4 ROUNDS
BATTERY 4 ROUNDS	
IN EFFECT.	
DEFLECTION 2992	DEFLECTION 2847
	WAIT (further commands are not given until fire for effect).

QUADRANT 953.

b. The charge, fuze setting (if any), and quadrant elevation for the nonadjusting batteries are determined and announced when fire-for-effect is ordered.

430. Selection of Charge

In selecting the charge to be used, the adjusting battery computer, supervised by the S3, selects the charge that is least likely to require changing due to subsequent corrections from the observer. Depending on the cannon used, there is some degree of overlap in ranges covered by various charges. If there appears to be a choice between two charges, the lower charge is selected to reduce time of flight and tube wear. However, during an adjustment it may be necessary to change from one charge to an-

other unless the observer's initial target location was accurate.

431. Fuze

The most effective fragmentation of any burst occurs in a plane approximately at right angles to the line of fall. This fragmentation is almost parallel to the ground with high-angle fire. Consequently, if time fuze is fired, a very slight error in height of burst may cause the burst to occur so high as to cause significant loss of fragmentation effect. Owing to the large height-of-burst probable error, the use of time fire is not normally employed with high-angle fire. The steep angle of fall eliminates the possibility of ricochet fire. Fuze quick or fuze VT normally is used.

a. Fuze quick is very effective when used in high-angle fire against personnel in the open because the projectile is almost vertical at the instant of detonation. Since the side spray of the burst contains most of the shell fragments, the effect is a spray in all directions out from the point of impact, approximately parallel to and very close to the ground.

b. The maximum lethality against personnel in the open is attained with a high explosive projectile and fuze VT. This combination has the advantages of a lateral spray effect obtained with fuze quick and the effectiveness of a very low air burst.

c. Because the side spray is horizontal, high-angle fire can be expected to be less effective than low-angle fire against personnel in the trenches or foxholes, regardless of the fuze used.

432. Deflection

a. The deflection index constructed for low-angle fire is also used for high-angle fire. Only when the firing chart is to be used exclusively for high-angle fire will a deflection index based on a high-angle registration be constructed.

b. Drift is large in high-angle fire and increases with an increase in time of flight; thus, in high-angle fire, drift increases as elevation increases and range decreases.

c. Drift changes too rapidly to permit use of

a deflection correction scale as used in low-angle fire. Because drift changes an appreciable amount for a relatively small range change, a correction to compensate for drift, which is determined at the elevation to be fired, is included in each deflection to be fired. Since drift is to the right, the correction is to the left and is always applied to the sum of the chart deflection and the deflection correction (if any).

Example: 155-mm howitzer, charge 5 GB, high-angle.

Range	Elevation	Chart deflection	Defl. corr.	Drift corr.	Piece deflection
8500	1060	3200	0	L45	3245

433. Site

a. For observed fires, site, because of the large angle of fall, normally can be ignored if the angle of site is no larger than plus or minus 30 mils. However, site must always be included in registrations, transfers of fire, and when several batteries are to mass their fires on a target when one battery has adjusted. Whether or not site is to be included is decided by the S3 and announced in the fire order. If the S3 desires that site be computed and used in the mission, the command INCLUDE SITE will follow HIGH ANGLE. Omission in the fire order of the command INCLUDE SITE means that site is to be ignored. Regardless of whether or not site is included in fire commands, the height of burst over range value (20/R), used with fuze VT in low-angle fire, is not used in high-angle fire because the descending branch of the trajectory is nearly vertical.

b. No GST is provided with which sites for high-angle fire may be computed. The C and D scales of any GST can be used to compute the angle of site. An increase in angle of site requires a decrease in quadrant elevation, because in high-angle fire the complementary angle of site factor is always greater than 1 and always has a sign opposite that of the angle of site. If the angle of site is plus, the comp site is minus; if the angle of site is minus, the comp site is plus. The comp site factor is a function of elevation. The comp site factor is determined from the Supplementary Data table of the firing tables.

c. When tabular firing tables are used to compute site, complementary angle of site is added algebraically to the angle of site and always results in a site which is opposite in sign to the angle of site.

Example: 155-mm howitzer (M109) charge 5 GB using tabular firing tables (FT 155-AH-2).

Chart range -----	8,500 meters
Elevation -----	1,059.2 mils
Altitude of battery -----	400 meters
Altitude of target -----	493 meters
Vertical interval -----	+93 meters
Angle of site (C and D scales, GST)	
(+11.1) -----	+11.1 mils
Comp site factor corresponding to	
elevation 1059.2 -----	-1.428
Comp site (+11.1 × (-1.428)) -----	-15.9 mils
Site (+11.1 + (-15.9)) -----	-5 mils
Quadrant elevation (1059 + (-5)) -	1,054 mils

d. To simplify the determination of site when high-angle fire is being used, a special site scale has been included on high-angle graphical firing tables. The site scale is located just below the elevation scale. This scale is referred to as the 10-mil site scale. The readings obtained from this scale give the site for 10 mils' angle of site at the elevation and charge that is being used. The site for any point is determined by dividing the angle of site to that point by 10 and multiplying the quotient by the factor read from the 10-mil site scale. The site derived from the 10-mil site scale will be slightly less accurate than the value computed from the tabular tables. The 10-mil site factor, considered negative, when multiplied by the angle of the site and divided by 10, will produce the proper sign and amount of the site. The sign of the site will be opposite that of the angle of site.

Example: 155-mm howitzer (M109) charge 5GB, using GFT.

Chart range -----	8,500 meters
Elevation corresponding to chart	
range -----	1,060 mils
Altitude of battery -----	400 meters
Altitude of target -----	509 meters
Vertical interval -----	+109 meters
Angle of site (C and D scales, GST)	
10-mil site factor (GFT) -----	-4.3
Site (+ 1.3 × (-4.3)) -----	-6 mils
Quadrant elevation (1060 + (-6))	1,054 mils

e. If a change in charge is required during the conduct of the mission, site should be re-computed for the new charge. Applying the site from one charge to the next will have the effect of lengthening any range change due to firing false site, so that a false range bracket may be established, and could result in entering fire-for-effect more than 50 meters from the target. Large changes in site may occur within a charge. However, in this case, failure to recompute site will result in a shortening of any range change so that false brackets will be avoided.

434. Precision Registration

a. During the adjustment phase of a high-angle fire precision registration, standard FDC procedures are followed, except that drift is combined with chart deflection for each round.

b. During the fire for effect (fig. 109), the same procedures are followed as in a low-angle fire registration except that, when the preponderance of the first three positive sensings from rounds fired at the center of the fork bracket is over in range, the elevation will be *increased* by $\frac{1}{2}$ fork, and when the preponderance of the positive sensings is short in range, the elevation will be *decreased* by $\frac{1}{2}$ fork.

- (1) When the elevation is changed by $\frac{1}{2}$ fork, the change in drift for the new elevation is negligible and may be ignored.
- (2) In computing the adjusted quadrant elevation, if the preponderance is over, the elevation change will be added to the mean quadrant elevation; if the preponderance is short, the elevation change will be subtracted from the mean quadrant elevation.

c. Site must be algebraically subtracted from the adjusted quadrant elevation to determine the adjusted elevation. The correct site can only be derived by successive approximation, since comp site is a function of elevation and not of chart range. Correct site is determined when the site computed agrees within 1 mil of the previously computed site. The last site computed is the correct site.

Example: Determination of adjusted elevation by successive approximation, 155-mm howitzer (M109), charge 4GB (fig. 248).

Angle of site	+8 mils
Adjusted QE	1,193 mils
Site fired during registration	-2 mils
10-mil site factor corresponding to elevation 1195	-1.8
First apparent site ($0.8 \times (-1.8)$) = -1.4	-1 mil
First apparent site agrees within 1 mil of site fired.	
Adjusted elevation	1,194 mils

d. GFT settings are established in the same manner as for low-angle fire. For example in c above, the GFT setting is GFT B: Charge 4, lot ZT, range 5680, elevation 1194.

e. The total deflection correction is determined by comparing chart deflection and adjusted deflection. The total correction is equal to the drift correction plus unknown corrections; or, solving for unknowns, unknown corrections are equal to the total (registration) correction minus the drift correction. In high-angle fire, the value of the unknown corrections is the deflection correction used for the charge.

Example: 155-mm howitzer (M109), charge 4GB, high-angle.

Adjusted elevation	1,194 mils
Adjusted deflection	3,318 mils
Chart deflection to registration point	3,252 mils
Total deflection correction ($3318 - 3252$) ..	L66 mils
Drift correction corresponding to adjusted elevation	L68 mils
Deflection correction ($L66 - L68$)	R2 mils

f. If no high-angle registration has been conducted and met or experience factors are unknown, a deflection correction of zero will be used. If a charge other than that with which the registration was conducted is to be fired, the deflection correction for the charge nearest the charge to be fired is used.

g. If high-angle registration precedes low-angle registration, the high-angle deflection correction will have to be recomputed after the deflection index has been displaced, since a new chart deflection would then be read to the high-angle registration point.

435. Preparation of Graphical Equipment

Graphical equipment is prepared for high-angle fire in the same way that it is for low-angle fire missions, except for the handling of deflection corrections.

a. *GFT.* The deflection correction for each charge is written on the GFT adjacent to the data for that charge (①, fig. 110).

b. *Aluminum GFT Fan.* The tabular firing table value of drift is printed on the ballistic scales of the aluminum GFT fan. The deflection correction for each charge determined from a precision registration, or from met data will be written on the ballistic scale. The deflection correction will be written to the right or left of the charge scale to which the particular deflection correction applies (②, fig. 110).

c. *Plastic GFT Fan.* High-angle ballistic scales for the plastic GFT fan either do not have drift values printed on the scale or have only the drift value printed corresponding to the short limit of each charge. If no high-angle registration data are available, drift values must be entered for each charge by using the value of drift from the tabular firing table or, when applicable, the drift value shown on the ballistic scale. If registration data are available, the total deflection correction is determined and entered opposite the appropriate graduation (③, fig. 110).

436. Data for Replot

a. The purpose of replot in high-angle fire is the same as in low-angle fire (para 416).

b. Regardless of whether or not site is included during the adjustment, the correct site must be algebraically subtracted from the adjusted quadrant elevation to obtain the adjusted elevation. The range at which the target is plotted is determined from the adjusted elevation. During the adjustment, the 10-mil site factor may change considerably and will result in an effective site at the end of the adjustment different than that used in the initial firing data. This error must be corrected if the target is to be plotted at its correct range.

RECORD OF PRECISION FIRE (FM 6-40)											
Date and time 10 JUNE 1965, 0800		Observer 44		Adjusting point REG PT 1		Battery B					
GFT setting GFT B :chg 4 ,lot Z T ,fg 5680 ,el 1194 ,ti						Deflection correction R2					
Chart data		Initial fire commands									
Deflection 3252	Corr L 67	BP Adjust									
Range 5680	El 1189	Sh HE	Lot ZT, HA								
Adjusted data		Si - 2 (ANGLE OF SITE + 2)								Chg 4	Fz Q
Deflection 3318	S/2 = 2	MF BP ①									
Elevation 1194	F = 7	Df 3319		Angle T 4.30							
Time	F/2 = 4	QE 1187									
Round no	Chart df	Df fired	Chart range	Time fired	El or QE fired (-2)	Observer sensing or corrections	FDC sensings				
							Range	Deflection			
①	3252+L67	3319	5680		1187	L30-200					
②	3249+L70	(3319)	5510		1201	+100		R			
③	3244+L68	3312	5600		1194	+50 FFE		R			
④	3246+L67	3313	5650		1190	+R	+	?			
⑤		(3313)			1198	-R	-	R			
⑥		3315			1194	-LN	-	R			
⑦		3317			1194	-R	-	R			
⑧		3319			1194	+LN	+	L			
⑨		(3318)			1190	+R	+	CORR			
⑩					1190	+LN	+				
11					EM						
12											
13	MEAN QE =				1192.0	CORR. DF.		3318			
14	EL CHANGE = $\frac{(4-2)}{(2 \times 2)} \times 7 =$				+1.2	B.P. DISPLACEMENT		0			
15	ADJ QE =				1193.2 = 1193	ADJ. DF.		3318			
16	10% SITE FACTOR (EL 1195) =				-1.8	CHART DF		3252			
17	1ST APP SITE (0.8 x -1.8) =				-1.4 = -1	TOTAL DF CORR		L66			
18	ADJUSTED EL (1193 - (-1)) =				1194	DRIFT CORR (EL 1194)		L68			
19						DF CORR		R2			
20											
21											
22											
23											
24											

DA FORM 6-12
1 OCT 64REPLACES DA FORM 6-12, 1 APR 57, EXISTING SUPPLIES OF WHICH
WILL BE ISSUED AND USED UNTIL 1 OCT 66 UNLESS SOONER EXHAUSTED.

Figure 109. Record of precision registration, high-angle fire.

Example: 155-mm howitzer (M109); GFT setting (from prior registration) is GFT B: Charge 5, lot WY, range 7050, elevation 1145, lot Y is GB.

Angle of site -----	+20 mils
Adjusted QE -----	1,162 mils
10-mil site factor corresponding to elevation 1162 -----	2.0
First apparent site $(+2.0 \times (-2.0) = -4.0)$ -----	-4 mils
First apparent adjusted elevation (1162 - (-4)) -----	1,166 mils
10-mil site factor corresponding to elevation 1166 -----	-2.0
Second apparent site $((+2.0) \times (-2.0) = -4.0)$ -----	-4 mils
Second apparent site agrees with first apparent site.	
Adjusted elevation $(1162 - (-4))$ -----	1,166 mils
Range corresponding to elevation 1166 (use GFT setting) used in plotting target -----	7,480 meters

c. After the adjusted elevation has been determined as described in *b* above, the deflection correction for the charge (or, if no correction has been determined for the charge fired, the correction from the nearest other charge which does have a correction) and the drift correction are subtracted from the adjusted deflection. If no deflection correction has been determined, the deflection for replot will be obtained by subtracting only the drift correction from the adjusted deflection. The result is the deflection for plotting the target.

Example: 155-mm howitzer (M109) charge 5GB;

Adjusted deflection -----	3245
Adjusted elevation -----	1166m
Drift correction corresponding to adjusted elevation -----	L62m
Deflection correction for charge 4 -----	L15m
Total deflection correction $(L62 + L15) =$ -----	L77m
Replot deflection $(3245 - L77)$ -----	3168m

d. If the terrain is rugged or if a large range change has been made since the angle of site was first computed (the angle of site may be first computed at the beginning of the mission or at the onset of determining replot data), the angle of site is recomputed for the replotted location of the target. The new map altitude is used in determining the new angle of site. If the new angle of site differs by

more than 1 mil from that angle of site previously computed, a new adjusted elevation and a corrected range for replotting the target must be obtained. This process is repeated until the correct angle of site (one that agrees within 1 mil of that previously computed) and adjusted elevation are determined. Data for replot are reported the same as for low-angle fire except that the type of fire and charge used is included; for example, coordinates_____, altitude_____, fuze_____, high-angle, charge_____, concentration_____.

437. Massing and Transfers

The high maximum ordinates and long times of flight encountered in high-angle fire make massing or transfer of fire less reliable than with low-angle fire. However, under stable weather conditions, successful transfers of fire within a single charge are practicable. The small area of range covered by each charge prevents establishment of definite transfer limits. Consequently, every effort should be made to obtain observation and to adjust each battery that is to fire on the target. During an adjustment, the 10-mil site factor may change considerably. This change will result in a site at the end of the adjustment different than that used in the initial commands. However, the error in range due to false site for the adjusting battery will be essentially the same range error required for the nonadjusting batteries to compensate for their false sites (there will be minimal error for differences between the battery altitudes, since initial site, even if incorrect, is included in missions where the battalion will mass). Therefore, several batteries may mass on a target, even if only one battery has adjusted.

438. Duties of Fire Direction Personnel

The duties of fire direction personnel in high-angle fire are the same as in low-angle fire except for minor modifications as stated in *a* through *c* below.

a. The S3 must include in the fire order the command HIGH-ANGLE in place of charge. He must also decide whether to include site.

(1) When adjustment is required prior to

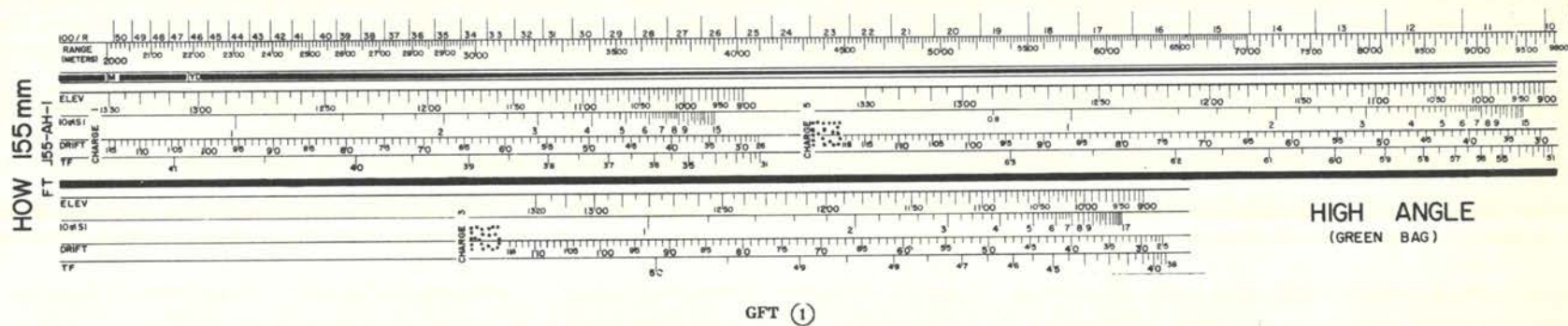
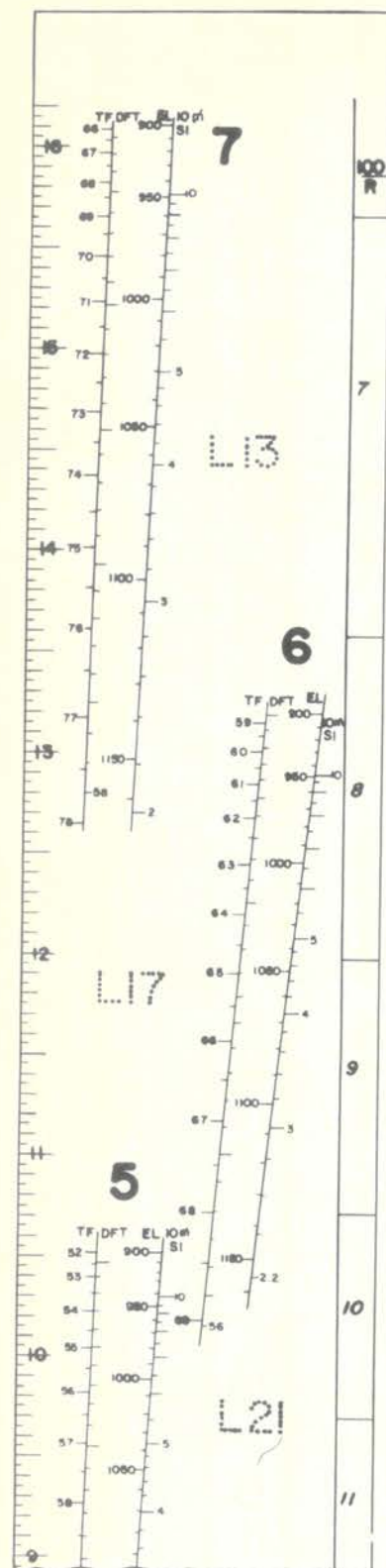
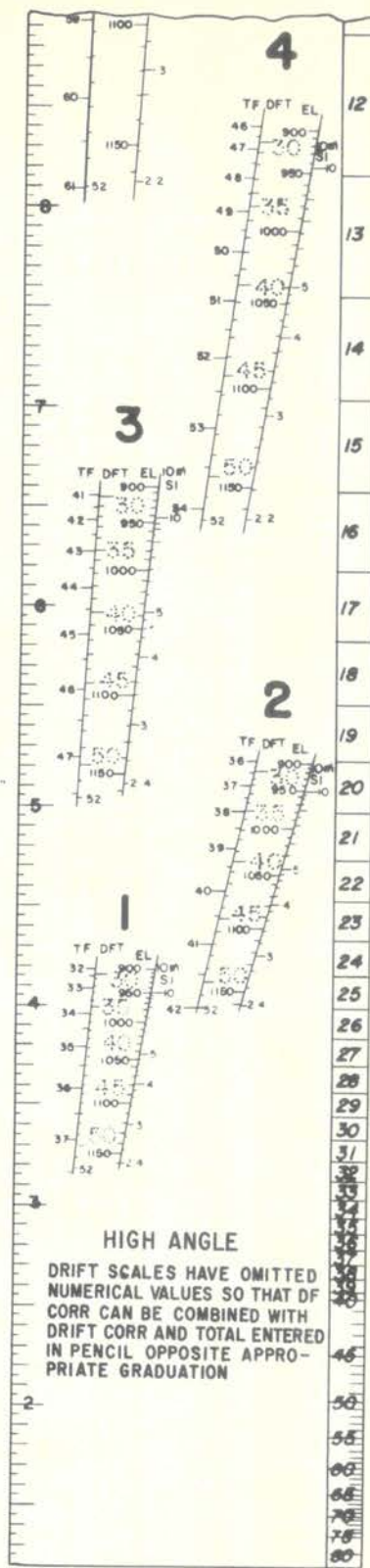


Figure 110. Deflection corrections, high-angle.



② Aluminum GFT fan



③ Plastic GFT fan

Figure 110—Continued.

massing the battalion and only one battery is to adjust, the battery that is centrally located should normally be designated as the adjusting battery to eliminate large differences in range.

- (2) For area missions to be fired by more than one battery, all batteries to fire should fire at center range, since dispersion in range will usually result from the effects of weather and the probable use of different charges by each battery.

Example: High-angle fire order.

BATTALION, BRAVO, LOT ZT,
HIGH-ANGLE, INCLUDE SITE,
FUZE VT, 2 VOLLEYS, CONCEN-
TRATION ALFA JULIETT 604

b. The computer must—

- (1) Select the charge to be fired.
- (2) Combine the drift correction, the deflection correction (if known), and the chart deflection and announce the algebraic sum as deflection.
- (3) If the fire order so designates, compute the site and add it to elevation to determine quadrant elevation. The 10-mil site factor and the angle of site announced by the VCO are used to compute site.

c. The VCO computes and announces angle of site rather than site, when the fire order contains INCLUDE SITE.

CHAPTER 25

FDC PROCEDURES FOR SPECIAL SITUATIONS

Section I. CHEMICAL SHELL

439. General

a. Chemical agents may be used to kill, injure, or harass personnel; to deny observation or use of an area; or to burn materiel. This section is concerned with the fire direction procedures used to employ chemical agents fired in chemical shells.

b. Paragraphs 210 through 212 contain a description of the uses of chemical shells and prescribes observer procedures for the adjustment of chemical shells.

440. Smoke Shells

a. *White Phosphorus (WP)*. Shell, WP, is a bursting type smoke shell which produces smoke, incendiary effect, and casualty effect. Against most targets, superquick fuze action is used. The action of the fuze and burster charge breaks the shell and scatters the phosphorus particles above ground. Since WP smoke rises, or pillars, it is not suited for maintaining a smokescreen; however, it is excellent for the initial buildup of a smokescreen.

b. *Smoke (HC)*. Shell, smoke, HC is a base-ejection shell and produces white smoke that is used primarily for screening. Always fired with time fuze, smoke, HC, is an effective screening agent but produces no casualty effect. HC smoke readily absorbs and retains moisture. This shell is more effective in rain or mist.

c. *Colored Smoke*. Colored smoke is base-ejected and is normally used for prearranged signals or as an aid to the observer in identifying his rounds. Colored smoke shell is fired with time fuze. Except for the color of the smoke (red, green, or yellow), colored smoke is similar to HC smoke (white).

441. FDC Procedures for Adjustment of Shell, WP

a. When fire for effect is to be fired with white phosphorus shell, the adjustment is conducted with shell HE, fuze quick.

b. WP projectiles are heavier than HE projectiles. When a change is made from shell HE to shell WP, a correction must be applied to compensate for the change in weight of projectile. The correction is determined in the following manner:

- (1) Determine the difference in the weights (squares) of projectiles by subtracting the weight of the shell HE used in adjustment from the weight of the smoke shell WP.
- (2) Determine from the Ground Data Table the correction for an *increase* in weight of projectile of one square at fire for effect chart range.
- (3) Determine correction by multiplying difference in weight of projectile ((1) above) by unit correction ((2) above).
- (4) Apply correction to fire for effect chart range. Place the hairline of GFT over the corrected range and read the elevation under the elevation gage line.

Example: 155-mm howitzer, charge 5.

Fire for effect chart range.....	6,040 meters
Weight of projectile HE.....	4 squares
Weight of projectile WP.....	7 squares
Difference in weight of projectile...	+3 squares
Weight of projectile unit correction (range 6,000)	+16 meters
Range correction (16×3).....	+48 meters
Corrected range (6,040+50).....	6,090 meters

Place hairline over 6,090 meters and read elevation under elevation gage line.

c. When necessary, the adjustment may be continued with one piece using shell WP until the smoke is in the proper place. The correction for weight of projectile is considered constant for a particular mission and need not be recomputed during the adjustment.

442. FDC Procedure for Adjusting Base Ejection Smoke Shell

a. When base ejection smoke shell is to be used, the adjustment is begun with one piece firing shell HE, fuze quick, and the lowest practical charge. The lowest practical charge is used to reduce the possibility of rupturing the cannister on impact and scattering the smoke cannisters.

b. When the observer has adjusted to within 100 meters of the adjusting point, he will usually request smoke shell and continue the adjustment until the smoke is at the proper location and height of burst. The procedures for firing base-ejection smoke shell are as follows:

- (1) Fuze time will be used. The fuze setting will be determined by subtracting 2 seconds from the fuze setting read under the time geline.
- (2) No height of burst correction (20/R) is applied when the adjustment with fuze time is begun. Height of burst will be adjusted by increasing or decreasing site in accordance with the observer's requests.

443. Building and Maintaining a Smokescreen (Shell, Smoke, HC)

a. To form an adequate smokescreen quickly, two rounds per point of impact should be fired as rapidly as possible. The smokescreen is then maintained by firing at the minimum rate necessary. The minimum rate is governed largely by the velocity of the wind. A guide to the proper rate of fire for 105-mm and 155-mm howitzers to maintain the screen is as follows:

<i>Rate of fire per point of impact</i>		
<i>Wind velocity</i>	<i>105-howitzer</i>	<i>155-mm howitzer</i>
3 MPH....	1 rd every 60 seconds	1 rd every 120 seconds
10 MPH....	1 rd every 40 seconds	1 rd every 80 seconds
15 MPH....	1 rd every 30 seconds	1 rd every 60 seconds

Note. The above rates must be modified based on what the observer sees on the ground.

b. Depending on the wind speed and direction and the size of the front to be screened, the spacing of the points of fall may be as great as 400 meters or as small as 30 meters. The points of fall must

be based on the observer's request and will be changed as necessary to correct for changes in weather and the tactical situation.

444. Toxic Chemical Shell

a. When toxic chemical shells are used, particular attention must be given to selection of the area into which the chemical shells will be fired. Wind direction, velocity, and temperature gradient are factors of great importance in this selection and will determine the number of chemical shells to fire to achieve the desired results. If friendly troops are downwind from the target area, they must mask. To compute safety distance, see TM 3-200.

b. Toxic chemical agents are employed either in a vapor (nonpersistent) or liquid droplet (persistent) form. Each form requires a different fire direction technique to achieve the best results.

- (1) When a chemical shell is used to produce a vapor hazard in the target area (non-persistent)—
 - (a) A point detonating fuze normally should be used.
 - (b) Surprise fire is essential. TOT of all available artillery is required to impact all shells into the target area within 30 seconds.
 - (c) Distribution of fire is accomplished by assigning a separate point of impact to each battery size unit.
- (2) When a chemical shell is used to contaminate the target area with liquid droplets (persistent)—
 - (a) Low airburst normally should be used.
 - (b) Surprise fire is not required.
 - (c) Distribution of fire is accomplished by firing each battery volley at a different point of impact. Normally, zone fire will give the best coverage.

c. When computing fire data for transfer of fire, a correction must be applied to the HE GFT setting to compensate for the increased weight of the toxic chemical projectile and an additional correction for a 1½ percent increase in air density. The correction is determined in the following manner:

Example: 155-mm howitzer, charge 5.

Entry range-----	6,030 meters
Fire for effect chart range-----	6,040 meters
Weight of projectile HE-----	4 square
Weight of projectile GB-----	7 square
Difference in weight of projectile-----	+3 square
Weight of projectile unit correction (range 6,000)-----	+16 meters

Range correction (16×3)-----	+48 meters
Air density correction for 1% (range 6,000)-----	+10.4 meters
Range correction ($10.4 \times 1\frac{1}{2}$)-----	+15.6 meters
Corrected range ($6040 + 60$)-----	6,100 meters
Place hairline over 6,100 meters and read elevation under elevation gageline.	

Section II. ILLUMINATING SHELL

445. General

a. A description of the uses of the illuminating shell and procedures for the adjusting of illuminating shells is contained in paragraphs 213 through 215. Illuminating shell is provided for the 105-mm howitzer, the 155-mm howitzer and gun.

b. Some of the factors to be considered in the employment of illuminating shells fired from the 105-mm howitzer and the 155-mm howitzer are listed below.

- (1) Initial height of burst = 750 meters.
- (2) Horizontal distance between bursts = 800 meters.
- (3) Burning time of flares = 60 seconds.
- (4) Rate of fire for continuous illumination = 2 rounds per minute.

446. Selection of Charge

When illuminating shell is used, the lowest possible charge should be fired in order to reduce the possibility of ripping the parachute when the flares is ejected from the shell.

447. Chart Data

a. The HCO plots and measures range and deflection as in any mission. Range is announced to the nearest 100 meters. Deflection is announced to the nearest mil.

b. The VCO determines and announces the vertical interval between the battery and ground level in the area to be illuminated.

448. Firing Data

In converting chart data to firing data, the computer must consider the type of adjustment.

a. *Deflection.* Deflection corrections determined by firing shell HE are disregarded. The

deflection to be fired depends on the type of adjustment.

- (1) *One gun*—The chart deflection is fired.
- (2) *Two guns*—The chart deflection is fired by both guns.
- (3) *Two guns, range spread*—The chart deflection is fired by both guns.
- (4) *Two guns, deflection spread*—The deflection for the right piece is the chart deflection minus 4 times $100/R$. The deflection for the left piece is chart deflection plus 4 times $100/R$.
- (5) *Four guns*—The two interior pieces fire the chart deflection. The deflection for the right piece is chart deflection minus 4 times $100/R$. The deflection for the left piece is chart deflection plus 4 times $100/R$.

b. *Elevation and Fuze Setting.* For each 100 meters in range, the firing table, part 3, shows the elevation and fuze setting for the optimum height of burst (750 meters above the guns) and the change in elevation and fuze setting for a 50-meter change in height of burst. The range at which elevation and fuze setting for each piece is determined depends on the type of adjustment. (Chart range is rounded to the nearest 100 meters in all cases.)

- (1) *One gun*—Chart range is fired.
- (2) *Two guns*—Chart range is fired.
- (3) *Two guns, deflection spread*—Chart range is fired.
- (4) *Two guns, range spread*—One piece is fired at chart range plus 400 meters; one piece is fired at chart range minus 400 meters.
- (5) *Four guns*—Flank pieces are fired at chart range; one interior piece is fired at chart range plus 400 meters; the

other interior piece is fired at chart range minus 400 meters.

c. Height of Burst Correction. The observer may make height of burst corrections in increments of 50 meters during adjustment. To determine the total height of burst correction, the computer adds the observer's cumulative height of burst correction and the vertical (para. 447b) rounded to the nearest 50 meters. The corrections to elevation and fuze setting are determined as follows:

- (1) Divide the total height of burst correction by 50. This gives the number of 50-meter increments.
- (2) Determine from the firing tables the values listed as change in elevation and fuze setting for a 50-meter change in height of burst.
- (3) Multiply the number of 50-meter increments from (1) above by the values from (2) above.

d. Fuze Setting and Quadrant Elevation. The fuze setting to be fired is the sum of the fuze setting (b above) and the fuze setting correction for height of burst (c above). The QE to be fired is the sum of the elevation (b above) and the elevation correction for height of burst.

448.1. Use of the Illuminating Graphical Firing Table

a. General. Graphical firing tables have been developed for use with the illuminating projectiles M118 and M314. The description below of the scales and data and the determination of firing data as outlined in paragraphs 448.2 and 448.3 are applicable to all models of the illuminating GFT.

b. Description.

(1) General.

- (a) The graphical firing tables, illuminating, FT 105-H-6 and FT 155-Q-3, consist of two rules each. Firing data for charge 3 (ascending and descending branches) and charge 4 (descending branch) are read from one rule; firing data for charges 5 and 7 (descending

branches) are read from the second rule.

- (b) The graphical firing table, illuminating, FT 105-AS-1, consists of two rules. Firing data for charge 4 (ascending and descending branches) and charge 5 (descending branch) are read from one rule; firing data for charges 6 and 7 (descending branches) are read from the second rule.

- (c) The graphical firing table, illuminating, FT 155-AH-1, consists of two rules. Firing data for charge 3 green bag (ascending and descending branches) and charge 5 green bag (descending branch) are read from the rule marked with a green stripe on each end; firing data for charges 6 and 7 (descending branches) are read from the second rule.

(2) Composition of Scales and Data.

- (a) *100/R Scale.* The correction in mils necessary to shift the point of burst laterally or vertically 100 meters for a given range may be read from the 100/R scale.
- (b) *Range scale.* Range is read on this scale to the nearest 10 meters.
- (c) *Quadrant elevation scales.* The quadrant elevation scales provide the quadrant elevation for a given range and height of burst above the battery.

1. Zero height of burst. The quadrant elevation scale for a zero height of burst above the battery is marked immediately below the range scale. For a given range read under the hairline on this scale the quadrant elevation to attain a graze burst at the level point.

2. Plus 600-1000 meter height of burst. Quadrant elevation scales are provided for a height of burst of plus 600 meters to plus 1000

meters above the battery in increments of 50 meters.

- (d) *Fuze setting scale.* The fuze setting (FS) scale is graduated in one fuze number intervals and is superimposed in red arcs on the quadrant elevation scales except for the zero height of burst.

448.2. Determination of Quadrant Elevation and Fuze Setting

a. To determine quadrant elevation and fuze setting for a given range and charge, place the hairline over the range to the point to be illuminated. Read at the intersection of the hairline and the selected quadrant elevation scale the quadrant elevation to fire. The quadrant elevation scale to select is determined by adding algebraically the optimum height of burst (750 meters) to the battery-target vertical interval in meters and expressing the sum to the nearest 50 meters. The fuze setting to fire is obtained by interpolating between the red fuze setting arcs for the point of intersection of the hairline and the selected quadrant elevation scale.

b. Data for the ascending branch is provided only for the lowest charge. A heavy black arrow on a quadrant elevation scale indicates that part of the trajectory which is at or near the summit, but which does not exceed the height of burst which it represents by 50 meters. The minimum range possible is attained by reading data for the ascending branch of the trajectory for this charge.

c. Example:

(1) Given:

(a) Chart range: 2500 meters.

(b) Vertical interval: +210 meters.

(2) Required: Quadrant elevation and fuze setting to fire. Use illuminating GFT (FT 155-Q-3).

(3) Solution:

(a) Select charge 3.

(b) Place hairline over chart range 2500 meters.

(c) Determine the quadrant elevation scale to use:

1. Optimum HOB: 750 meters.

2. Vertical interval: +210 meters.

3. Quadrant elevation scale to use $(750 + 210 = 960)$: 950 meter height of burst.

(d) Read, at the intersection of the hairline and the 950 meter quadrant elevation scale, the quadrant elevation to fire: 620 mils.

(e) Interpolate between the red fuze setting arcs bracketing the point of intersection of the hairline and the 950 meter quadrant elevation scale to obtain the fuze setting to fire: 13.2.

d. The determination of quadrant elevation and fuze setting for descending branches is identical with the procedure outlined for the ascending branch.

448.3. Determination of Firing Data Based on Subsequent Observed Height of Burst Correction

a. Data based on subsequent height of burst corrections are determined in the following manner:

(1) Determine the quadrant elevation scale to use:

(a) Observer corrections to height of burst are always given in multiples of 50 meters.

(b) Observer corrections are added algebraically to the height of burst previously used to obtain the height of burst to be used for that subsequent correction.

(2) Using the appropriate quadrant elevation scale, determine the quadrant elevation and fuze setting as outlined in paragraph 448.2.

449. Corrections

The proper height of burst, time of burning, and distance between bursts of adjacent volleys may vary from one projectile lot to another because of variations in the illuminant. Storage conditions and length of storage may cause a variation in performance of the illuminant.

Large variations from the optimum height of burst can be expected. To prevent waste of ammunition, the FDC must record the corrections from all adjustments and determine the best height of burst for each ammunition lot. A correction to obtain the best height of burst should be applied at the start of the adjustment.

Section III. PROPAGANDA SHELL

450. General

a. Artillery may be used to deliver psychological warfare leaflets. Pinpoint accuracy is not required for propaganda missions. Twenty-five rounds from a 105-mm howitzer normally will cover an area 500 by 500 meters. Corps artillery or higher headquarters normally will issue the order to fire propaganda shells and will specify the area to be covered and the amount of ammunition to be expended.

b. There is no standard propaganda shell. Ordnance will prepare and issue the ammunition. Usually, an HC smoke projectile, with the filler and booster replaced by leaflets, is used. Ordnance must weigh the shells and mark the weight on the shells.

451. FDC Procedure for Firing Propaganda Shell

Data are determined as in a normal HE mission with the following exceptions:

a. The height of burst above ground is initially 100 meters. Wind velocity and direction may affect the leaflets in such a way that a lower height of burst may be requested by the observer.

b. Because of the large variation from standard for weight of projectile, a correction must be determined and applied to chart range. Elevation and fuze setting are determined at the corrected range, using the HE GFT setting, if any.

Section IV. ASSAULT FIRE

452. General

Assault fire is a special technique of indirect fire. The FDC personnel, as part of the assault fire team, should make certain preparations prior to the occupation of position. Firing charts should be plotted and initial firing data computed. Also, deflection shift and quadrant change cards should be prepared. The planning and preparations should provide excellent initial data, resulting in a short adjustment phase.

453. FDC Procedure for Assault Fire

a. To obtain the necessary accuracy, an FDC is employed for each emplaced weapon. Normal observed fire and FDC procedures are used during the adjustment. The maximum charge which will clear the intervening crests is used to effect maximum muzzle velocity and penetration. The tabular firing table must be used. The minimum range on GFT's for the higher charges precludes the use of GFT's.

b. Observer procedures for assault fire are described in paragraphs 216 through 221. If during the mission the observer changes from fuze delay to fuze concrete piercing (CP), a correction of UP 1 METER is made in the FDC to compensate for the ballistic difference between the fuzes.

c. After the chart data are determined for the first round in fire for effect, the use of the firing chart is discontinued. During the remainder of the mission, a two-man team, consisting of a deflection computer and a quadrant computer, compute the data to place the burst directly on the target.

- (1) As an aid in computing required deflection changes, the deflection computer

prepares, prior to the start of the mission, a deflection shift card (fig. 111) for the chart range to the target. This card is prepared by using the C and D scales and M gage point of any GST. The range to the target is set on the C scale opposite the observer's correction on the D scale, and the deflection shift in mils is read opposite the M index. The deflection shift in mils is rounded to the nearest whole mil for observer corrections greater than 2 meters and to the nearest $\frac{1}{4}$ mil for observer corrections of 2 meters or less. A deflection board (fig. 31) is used by the battery to set off $\frac{1}{4}$ -

mil units of deflection. To determine a new deflection to include the observer's corrections, the required deflection shift is applied to the previous deflection by use of the LARS rule (left, add; right, subtract).

Example: Chart range 1,500 meters.

Previous df fired	Observer's correction	Df shift from card	New df command
2610.....	R7	R5	2605
2605.....	L4	L3	2608
2608.....	L2	L1 $\frac{1}{4}$	2609, L $\frac{1}{4}$
2609, L $\frac{1}{4}$	R1	R $\frac{3}{4}$	2609, R $\frac{1}{2}$
2609, R $\frac{1}{2}$	L $\frac{1}{2}$	L $\frac{1}{4}$	2609, R $\frac{1}{4}$

- (2) As an aid in computing the required quadrant change (to the nearest 0.1 mil), the quadrant computer prepares in advance a quadrant change card (fig. 112) for the chart range to the

target. This card is prepared in the same manner as the deflection shift card. The quadrant change in mils is rounded to the nearest whole mil for observer corrections greater than 2 meters and to the nearest 0.1 mil for observer corrections of 2 meters or less. The gunner's quadrant is used throughout the mission. To determine a new quadrant to include the observer's correction, the required quadrant change is applied in the appropriate direction to the previous quadrant fired.

Example: Chart range 1,500 meters.

Previous QE fired	Observer's corrections (m)	QE change from card (mil)	New QE command
30.0.....	UP 4	+3	33.0
33.0.....	DOWN 2	-1.4	31.6
31.6.....	UP $\frac{1}{2}$	+0.3	31.9

Deflection shift card	Chart range 1,500 meters
Observer's deflection Correction (in meters)	Deflection shift (in mils)
1/2	1/4
1	3/4
2	1 1/4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

Figure 111. Deflection shift card.

Quadrant change card	Chart range 1,500 meters
Observer's site Correction (in meters)	Quadrant change (in mils)
1/2	0.3
1	0.7
2	1.4
3	2
4	3
5	3
6	4
7	5
8	5
9	6
10	7

Figure 112. Quadrant change card.

Section V. DESTRUCTION MISSIONS

454. General

a. A destruction mission is a mission to destroy a target by one or more direct hits. There are two primary considerations in the selection of the weapon-charge combination to be used. A large enough projectile to accomplish the mission should be selected, and the weapon charge combination should give the smallest PE_r possible. Most destruction missions should be fired by medium or heavy artillery; however, in some situations light artillery can be effective. The 8-inch howitzer is an excellent weapon for a destruction mission because of its small probable error and the effectiveness of its projectile.

b. A destruction mission is a precision mission. Because the destruction of the target is the objective, the observer, not the S3, will terminate the mission as soon as destruction has been accomplished.

455. FDC Procedure for Destruction Mission

a. The correct deflection for destruction missions is determined in the same manner as in a precision registration.

b. An adjusted quadrant elevation is determined after six positive FDC range sensing in

fire for effect. The adjusted QE is computed to the 0.1 mil. Firing is continued, if necessary, with the adjusted QE (nearest 0.1 mil). After each succeeding group of six positive FDC range sensings, a new adjusted QE is computed. In computing the second adjusted QE, one-half of the computed elevation change is applied to the old adjusted quadrant elevation. In computing the third adjusted QE, one-third of the computed elevation change is applied. In computing the fourth and any succeeding adjusted QE's one-fourth of the computed elevation change is applied.

c. Since weapons used in destruction missions are selected for small PE_r, a large percentage of the time 4 PE_r will be less than 50 meters. When the trial range is announced by the HCO, the S3 should determine if 4 PE_r is less than 50 meters and if it is, he should establish a full fork bracket as outlined in paragraph 297.1.

Example: 155-mm How. *Note.* S3 determines PE_r = 8.
 Trial Rg Therefore 4 PE_r
 2010 meters. = 32 which is
 F = 2 less than 50. S3
 used full fork
 method.

<i>Rd Nr in FFE</i>	<i>QE</i>	<i>FDC reg sensing</i>	<i>Comment</i>
1	116	+	Drop Fork (2 mils)
2	114	+	Drop Fork (2 mils)
3	112	—	Split Brk Fire (3)
4	113	—	
5	113	+	
6	113	—	
7	114	+	Prep (—) Fire (2)
8	114	+	Where (+) was obtained compute first adj. QE using rounds 2, 4, 5, 6, 7, & 8 and continue as in paragraph 455 (b) above.

d. When a projectile-fuze combination other than HE-Quick is desired, the change is made after the first adjusted QE is computed. If the desired combination has different ballistic prop-

erties, appropriate corrections for nearest listed chart range must be applied.

Example: 8" How, Chg 5, Rg 5050

First Adj QE = 314.5 mil (Sh HE,
Fz Q)

S-3 directs fuze CP

FT 8-J-3 Data:

Correction for Fz CP (1% in-
crease air density) = +9.0 M

C = 4.9 mil

Correction to be applied:

$$\frac{+9.0}{100} \times 4.9 = +0.44$$

0.4 mil increase in QE

Section VI. BARRAGES

456. General

A barrage is a prearranged barrier of fire. It is designed to protect friendly troops and installations by impeding enemy movements across defensive lines or areas. The normal ground use of a barrage is to establish prearranged close-in defensive fires which include coordinated employment of other artillery fires, minefields, obstacles, final protective machinegun fire, and mortar barrages. Each battery is assigned only one barrage. The battery is normally laid on that barrage when not firing other missions. The barrage may be fired on prearranged signal or on call from the supported unit. The firing of a barrage may be repeated on call as often as necessary. When possible, the data for the barrage should be verified or corrected by the firing of check rounds.

457. Characteristics of Barrages

The firing of a battery barrage, either individually or coordinated with other batteries, is based on the following:

a. Width of Barrage (fig. 113). The width (or the length) of the barrage, which can be covered by a single battery without shifting its fire, should not exceed the width of an open sheaf as shown in table IV. When necessary, the width (length) of the barrage may be increased by agreement between the commanders of the artillery and the supported unit. However, the effectiveness of fire will be decreased.

b. Preparation of Data. The barrage may be at any angle to the direction of fire. Special corrections normally are used to place each burst in the proper position. Map data for a barrage are taken from the center point of the barrage

line. The angle between the barrage and the direction of fire is used to secure a plot of the barrage on the device (M10 plotting board) that is used to compute individual corrections for each piece. Firing data are determined by using normal procedures except for—

- (1) *Distribution.* A barrage is fired with special corrections.
- (2) *Method of fire.* Fire is continuous fire at maximum rate.

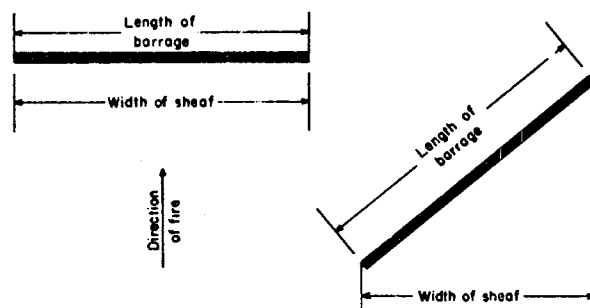


Figure 113. Barrage.

c. Barrages of Greater Width Than an Open Sheaf. When it is necessary to employ a barrage of greater width than an open sheaf, the procedure is to shift the fire from one portion of the line to the other. This may be done by the battery as a whole by employing shifting fire. Much greater protection is obtained if sufficient reinforcing artillery is assigned to allow each battery to limit its fire to the width of an open sheaf. Fire is shifted by laying the battery (pieces) first on one part and then on other parts of the barrage to be covered. Continuous fire by piece is delivered alternately on each part of the target.

Section VII. COMBINED ADJUSTMENT

458. General

a. Observer procedure for combined adjustments is described in paragraphs 222 through 227.

b. Targets or adjusting points may be designated by one observer or the S3. When direct communication between observers is impossible, the FDC must coordinate the operations for the observers.

c. Only one piece is used in adjustment.

459. FDC Procedure for Combined Adjustments, OP's Plotted

a. For combined adjustments, the target is plotted and firing data determined in the normal manner. Orientation data for the OP's may be determined in the manner prescribed in paragraph 312.

b. After the initial round is fired and the observers have reported the azimuths (or deviations), rays are drawn from each OP at the reported azimuths. The intersection of the rays is the location of the burst. A range and deflection correction to place the burst at the target is measured. New firing data is computed and fired.

Example: 155-mm howitzer, charge 5.

Chart range to target----- 5,900 meters

Chart deflection-----	2,827 mils
QE fired (el (297) + site (+6))-----	303 mils
Fired deflection (df corr 0)-----	2,827 mils
Measured range to burst location-----	5,790 meters
Correction for range (5,900-5,790)-----	+110 meters
Corrected range (5,900 + 110)-----	6,010 meters
Elevation corresponding to 6,010 meters---	305 mils
New QE (305 + (+6))-----	311 mils
Measured deflection to burst location-----	2,833 mils
Deflection correction (2,827-2,833)-----	R6 mils
New deflection (2,827 + R6)-----	2,821 mils

Section VIII. SOUND, FLASH, AND RADAR MISSIONS

460. General

The target acquisition battalion organic to corps artillery has the means for locating targets, adjusting and registering friendly artillery fire, calibrating artillery, collecting battlefield information, and performing battlefield surveillance. The target acquisition batteries of the battalion contain sound, flash, and radar platoons which are deployed to cover common areas. Firing battalions can obtain support from the target acquisition battalion through normal channels. The techniques employed by sound, flash, and radar units are covered in FM 6-122 and FM 6-160.

461. Sound Ranging

Sound ranging is employed to locate hostile artillery and to adjust friendly artillery fire. Sound locations and adjustments are not affected by poor visibility; however, high winds interfere with the operation of sound ranging equipment.

462. Flash Ranging

Flash ranging is the most accurate means of locating targets; however, the efficiency of the flash ranging observation posts may at times be limited by poor visibility and adverse terrain. The flash ranging platoon is used to—

- Locate hostile artillery.
- Adjust and register friendly artillery.
- Collect battlefield information.
- Perform comparative calibration of artillery.

463. Counterbattery Radar

The target acquisition battalion counterbattery radar is not affected in operation by poor visibility

or darkness. However, mountainous terrain makes the selection and occupation of radar positions and location of targets more difficult. The adjustment of fire by radar is difficult and time consuming. It should be used when no other means are available. The same radar position cannot be used effectively for both locating hostile weapons and battlefield surveillance. Counterbattery radar is used to—

- Locate hostile artillery.
- Adjust and register friendly artillery.
- Perform battlefield surveillance.

464. Countermortar Radar

The divisional countermortar radars are not affected in operation by poor visibility or darkness. However, mountainous terrain makes the selection and occupation of radar positions and location of targets more difficult. Countermortar radar is utilized to—

- Locate hostile mortars.
- Locate hostile artillery firing high-angle fire.
- Register friendly artillery.

465. Target Designation

a. Targets located by sound, flash, or radar platoons of the target acquisition batteries are reported to division or corps artillery. Reports normally will include coordinates and height of target as well as times active, accuracy of location, and description of target. In the absence of survey, the target acquisition unit can report targets in relation to a reference point, previous concentrations, or registration point which has been located relative to both the firing battalion and the locating agency (FM 6-122

and FM 6-160). Sound and radar platoons must determine the heights of targets from maps; however, flash platoons can always determine relative heights.

b. The location of a target or registration point can be given to the target acquisition battalion as coordinates or in relation to a known point.

466. FDC Procedure for Targets Located by Sound, Flash, or Radar

a. Depending on the accuracy of location, type of target, and time available, targets located by sound, flash, or radar may be attacked with or without adjustment.

b. When targets are to be attacked without adjustment, FDC procedures are the same as those used for any fire for effect target received from higher headquarters. Sound ranging platoons may request one round to be fired after the fire for effect to plot the location of the effect, because many rounds bursting at the same time make sound tapes difficult to read.

c. When sound, flash, or radar is used to conduct the adjustment of fire on a target, the FDC will receive a standard fire request and standard corrections; procedures are the same as those used in a normal adjustment by a forward observer except that—

- (1) Time of flight is given to the adjusting agency (e.g., sound platoon) prior to commencing fire. ON THE WAY and SPLASH are always given for each round.
- (2) All adjustments are conducted with one weapon.
- (3) Flash adjustment may contain refined corrections which would not be encountered in an observer adjustment (e.g., RIGHT 110, ADD 550), because each burst is accurately located.

- (4) Sound-on-sound adjustments (FM 6-122) must be conducted with fuze quick.
- (5) Radar personnel may request the range and azimuth to the target to assist in orienting the antenna for picking up the rounds.
- (6) Adjustments by sound, flash, or radar normally will use less ammunition but may be slower than adjustments by one observer, owing to the necessity of plotting each round prior to determining corrections.

467. Conducting Registration and Calibration

a. Sound, flash, and radar units can register artillery (FM 6-122 and FM 6-160). Registration by sound ranging is the least accurate of these three methods. It should be used only when registration by any other means is impossible. The coordinates and altitude of the registration point (point selected for CI or HB) should be determined by the firing battalion in coordination with the target acquisition battalion.

b. If the registration is to be a CI or HB, the number of rounds fired is determined at the FDC; however, the target acquisition battalion may request one or more rounds fired AT MY COMMAND in order to orient the observers. These rounds may be requested to assure positive identification in the case of sound ranging or radar. A specified interval between rounds may also be required. The location of the CI or HB is computed by the target acquisition battalion and reported to the firing battalion. In the case of a precision registration, normal FDC procedures are followed.

c. The flash platoon of a target acquisition battalion can provide mean burst location for comparative calibration.

Section IX. VERY HEAVY ARTILLERY FIRE DIRECTION PROCEDURES

468. General

a. The mission of very heavy artillery is to provide general support and reinforcing fire to units of division, corps, or field army.

b. The fire direction procedures described in paragraphs 386 through 467 apply to very heavy artillery except for the specific differences that are covered in this section.

469. Firing Charts

a. The deliberate method of employment of very heavy artillery usually permits adequate survey to be accomplished before firing. A surveyed firing chart is normally used.

b. The pieces of a very heavy artillery battery are often widely dispersed. Therefore, it may be necessary to plot the location of each piece or the platoon center of each platoon.

c. When each piece or the platoon center is plotted on the firing chart, tick marks and deflection indexes are identified by using the standard battery color code together with the number of the piece or platoon.

470. Procedure When the Fork is Greater Than 150 Meters or Less Than 50 Meters

a. At long ranges, the range probable error for very heavy artillery can exceed 38 meters and the fork will exceed 150 meters. When the range change corresponding to one fork is 150 meters or greater, fire for effect is begun when a 200-meter bracket is split. In such cases, the S3 should notify the observer to begin fire

for effect when a 200-meter bracket is split. This procedure is prescribed because, when the probable error is large, the rounds fired to impact 50 meters apart (as a result of ADD (DROP) 50) may in fact, impact at the same point.

b. To determine the range change corresponding to 1 fork, the range probable error (at the elevation being fired) is multiplied by 4.

c. Procedure to be used when the fork is less than 50 meters is described in paragraph 297.1.

471. Destruction Missions

a. Normal procedures for a destruction mission apply to very heavy artillery.

b. Prior to attacking a point target, the S3 should compute the single shot hit probability (SSHP) (ch. 29). With the SSHP, he should enter the assurance graph (para. 554) for the estimated required hits at the desired level of assurance. From the graph, he can read the probable number of rounds required. The probable number of rounds required and the available supply rate may determine if the mission should be fired.

Section X. DEAD SPACE

472. General

Dead space is the area within the maximum range of a weapon which cannot be covered by fire from a particular position because of intervening obstacles, the nature of the ground, characteristics of the trajectory, or the mechanical limitation of elevating and depressing the tube. Dead space areas can be determined only with an accurate contour map. Trajectories for all charges, low- and high-angle fire, must be considered in computation of dead space. Dead space is a more serious problem for guns than it is for howitzers.

473. Limits

The near limit for any dead space area is the grazing point of the trajectory; i.e., the point nearest the battery where the trajectory intersects the ground (fig. 114). The far limit is the first point of impact beyond the near limit or grazing point. Additional limits, particularly at very short ranges, may be imposed by the

characteristics of the fuze fired. These additional limits are often undeterminable owing to varying factors of the position, weapon, and ammunition. Some examples of possible additional limits due to fuze characteristics are as follows:

a. VT fuzes require a minimum arming time range, short of which they will not function.

b. Time fuzes are restricted to the minimum and maximum effective functioning times.

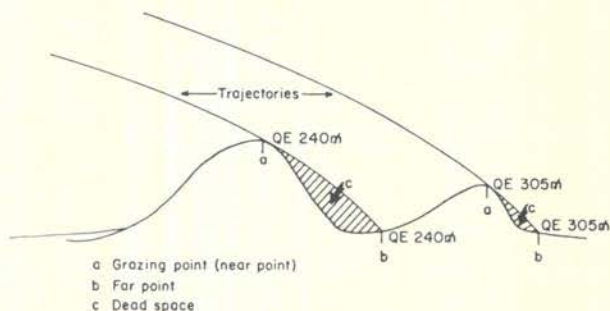


Figure 114. Dead space profile.

474. Determination of Dead Space

Dead space may be determined by a quadrant elevation ray method. The dead space for one ray is determined, and the process is repeated for such additional rays as necessary to clearly indicate the extent of the dead spaces.

a. The procedure for each charge and type of fire is as follows:

- (1) A ray is drawn on a map overlay from the plotted position of the piece through the desired point on the intervening terrain feature. By inspection, the highest point of the mask considered is determined. The quadrant elevations of this point and other points on the ray that are 50 to 100 meters beyond the highest point of the mask are determined. The point requiring the greatest quadrant elevation marks the beginning of the dead space and is known as the grazing point.
- (2) The point of impact, or far limit of dead space, is determined by finding a point beyond the mask which requires the same quadrant elevation as the grazing point. The process is one of trial and error. A test point of impact is selected by inspection, based on the range corresponding to the quadrant elevation for the grazing point. The quadrant elevation for the test point is determined. If the quadrant elevation is less than that for the grazing point, the point is in dead space; if it is greater than that for the grazing point, the point is beyond dead space. By repeating the process, the point of impact can be determined to any desired degree of accuracy.

- (3) When friendly elements occupy the terrain that is being considered, quadrant elevation must be increased by safety factors of 2 forks and 5 meters (or proper vertical clearance for fuze VT) at piece mask range.

- (4) Additional dead space areas along the ray are determined in the same manner as in (1) and (2) above.

b. Except in very symmetrical terrain, adjacent rays should form an angle of no greater than 100 mils. In extremely hilly terrain, it may be necessary to determine dead space at 50-mil or smaller increments. The smaller the increments, the more accurately the diagram will reflect true dead space. Dead space for additional rays is determined in the same manner as in *a* above.

475. Dead Space Chart

a. The area of dead space may be outlined on a chart or map by connecting points of determined quadrant elevation, corresponding to the same hill mask, on adjacent rays. Dead space is shaded or labeled.

b. Unless directed otherwise, dead space charts forwarded to higher headquarters need show only dead space areas for low-angle and high-angle fires without regard to charge. Dead space charts for battalion FDC should be improved as time permits. Improved charts should show charge capabilities as well as dead space areas for low-angle and high-angle fires.

c. In rugged terrain, it may be necessary to determine if a target is in dead space prior to the completion of a dead space chart. The dead space is determined on a ray drawn from the battery to the target using the procedure described in paragraph 474a.

Section XI. MISCELLANEOUS

476. Data Sheets

a. *Data Sheet.* Since prearranged fires are fire for effect missions, the latest corrections must be determined to the chart data to maintain correct fire commands. The chart and firing data for prearranged fires normally are predetermined and entered on battery data sheets (DA Form 6-14) to facilitate maintaining firing data with current corrections applied.

The battery data sheet is usually prepared at the fire direction center; and, if time permits, the data from the battery data sheet are converted to individual piece data and entered on section data sheets (DA Form 6-13) by the computer at the battery fire direction center.

b. *Firing Battery Data Sheet (DA Form 6-14).* A sample firing battery data sheet is

FIRING BATTERY DATA SHEET

(FM 6-40)

BATTERY		COORDINATES		ALTITUDE OF BATTERY		TIME		DATE		PAGE NO.														
C		5736038479		397		2000		1 JUN 64		1														
CHART DATA												FIRE COMMANDS												
CONC NO.	COORDINATES	TIME		TIME OF FLIGHT (Sec)	DEFLECTION		RANGE	ALT	SITE DIFF ALT	SP CORR	CHG	CORR	DF	TI	ZONE	QE	REMARKS							
		FROM	TO		CORR	CHART OF												EL	DIFF ALT	SITE HT OF BURST	SH	FZ	INDIVIDUAL SHEAF CORRECTION	INDIV CORR
BA 103	53395 39542	0530	0532		L 1	2477	4490	401	+1		5													
								+4		HE	Ti						276							
							270	20/R	+5	QX	B(6)													
BA 101	53843 37558	0534	0537		O	3003	3970	410	+4		5													
								+13		HE	D						227							
							223			QY	B(4)													
BA 104	50631 36525	0539	0541		L 4	3031	7660	437	+6		7													
100								+40		HE	VT													
METER ZONE							300	20/R	+3	QY	B(2)													
BA 102	52440 37802	0543		20	L 2	2882	5440	380	-4		5													
								-17		HE	Ti						TOT							
							347	20/R	+4	QX	B(5)						0543							

DA FORM 6-14

REPLACES EDITION OF 1 APR 57, EXISTING SUPPLIES OF WHICH WILL BE ISSUED AND USED UNTIL 1 NOVEMBER 1964 UNLESS SOONER EXHAUSTED.

Figure 115. Firing battery data sheet.

shown in figure 115 and is self-explanatory except for the following:

- (1) The times entered indicate when firing is started and lifted.
- (2) Time of flight is normally omitted. When time of flight is significant, as it is for final fires on positions about to be assaulted by infantry, TOT's, high-angle fire, or fires at extreme ranges, this factor is entered and is used at the battery to modify the listed time of firing.
- (3) Column for angle of site and comp site is used for site when GST is used to determine site.
- (4) Columns for special corrections and zone fire are used only when applicable.
- (5) The remarks column contains any special instruction.
- (6) When new corrections are obtained,

the old commands are lined out, instead of erased, and the change is entered.

477. Fire Capabilities Chart

The fire capabilities chart of the battalion shows the area that can be reached by the combined capabilities of the batteries of the battalion with on-carriage traverse or, if directed, additional limits. The area that can be reached by three-fourths of the pieces in deflection and range is the fire capability of the battery. The fire capabilities chart of the battalion, as reported to higher artillery headquarters, may show the area which can be reached by each battery or the combined coverage of all the batteries. The chart is used in conjunction with the dead space chart for determining areas not covered by units and for selecting units to fire on targets. For detailed information and illustrations of the fire capabilities chart, see FM 6-21.

CHAPTER 26

OBSERVED FIRING CHARTS

Section I. INTRODUCTION

478. General

Immediate delivery of supporting fires must not be delayed by an incomplete survey or lack of suitable maps. When such conditions exist, an OBSERVED FIRING CHART is constructed. An observed firing chart is a chart on which the relative locations of the battery position(s) and targets are established by the adjustment of fires. An observed firing chart is normally constructed on a grid sheet.

479. Initial Observed Firing Charts

a. If maps and survey data are not available when a battery occupies a position, the battery must use an initial observed firing chart until such time as a registration has been completed or maps and survey data become available.

b. To construct an initial observed firing chart, assign the battery center assumed coordinates and plot it on a grid sheet. In the usual manner, construct a temporary deflection index for the direction in which the battery is laid. The fire direction officer, based on a

general knowledge of the situation, must determine an approximate azimuth to the center of sector and a range at which to fire the first round to insure the safety of friendly forces.

c. The observer's initial fire request must include MARK CENTER OF SECTOR, if no other method of target location is available. The data for the initial round is determined from the estimated direction and range to the center of sector. Fire direction procedures in the conduct of fire are generally the same as those used with a surveyed firing chart. Upon the completion of a mission, the observer may use the concentration as a known point in reporting other target locations. As long as the ballistic variables of weather, materiel, and ammunition remain constant, any previously fired concentration may be refired using the same data.

d. A registration should be conducted as soon as possible in order that a battery observed firing chart may be constructed.

Section II. BATTERY OBSERVED FIRING CHARTS

480. General

a. To construct a battery observed firing chart, assumed coordinates and altitude are assigned to the registration point. Based upon the adjusted data, the location of the battery with respect to the registration point is determined. The battery is plotted on the back azimuth of the azimuth of fire. If an impact registration is fired and site cannot be approximated, the battery is plotted at a range corresponding to the adjusted quadrant elevation. If a time registration is fired, the range corresponding to the adjusted time is used. The

derived site is used to determine the relative altitude of the battery. The deflection index is constructed at the adjusted deflection and a deflection correction scale is prepared.

b. The major source of inaccuracies in observed firing charts is the inclusion of false site and its corresponding range error into the polar plot range. Errors due to false site can be reduced by using time fuze and selecting the charge which minimizes the height of burst probable error.

c. The battery observed firing charts may be consolidated into a battalion chart if all bat-

teries register on the same registration point (para. 488-491).

481. Determination of Direction for Polar Plotting

a. At the completion of the registration, the battery executive officer measures the azimuth and the orienting angle (if an orienting line has been established).

b. If an orienting line has been established, the azimuth from the battery to the registration point is determined by subtracting the orienting angle measured by the battery executive officer from the azimuth of the orienting line. If there is no orienting line the azimuth measured by the battery executive officer is used.

c. The direction for polar plotting, the battery is the back azimuth of the direction determined in *b* above.

482. Determination of Range and Altitude, Percussion Plot

a. When maps and survey data are not available, the determination of accurate site is impossible. However, every effort must be made to determine the approximate site. If the determination of even an approximate site is not feasible, the site is assumed to be zero. The range for polar plotting is the range corresponding to the adjusted elevation (adjusted QE minus the site); the hairline of the GFT is placed over the adjusted elevation and the range is read under the hairline.

b. The vertical interval between the battery and the registration point must be estimated if possible. The vertical interval is applied to the assumed altitude of the registration point to determine the altitude of the battery.

483. Determination of Range and Altitude, Time Plot, Site Unknown

a. The major sources of error in range in an observed firing chart, percussion plot, is the lack of an accurate site and the effects of unknown variations from standard conditions. If the site is unknown or incorrect, the derived adjusted elevation is in error by the amount of the error in site. To derive the polar plot range from a false elevation introduces a false range. However, the effect of site on the fuze setting is usually small. Therefore, the adjusted time can be used as a good indicator of the adjusted elevation and the polar plot range.

b. A site may be derived by subtracting the elevation corresponding to the adjusted time (minus the average fuze correction, if any) from the adjusted quadrant elevation. The vertical interval is determined from the GST by multiplying the polar plot range by the derived site. The altitude of the battery is then determined by applying the vertical interval to the assumed altitude of the registration point.

Example: A 155-mm howitzer battery using charge 5 has registered on a registration point.

Adjusted QE.....	315 mils
Adjusted time.....	21.2 seconds
Average fuze correction.....	None
Range corresponding to time 21.2 seconds (polar plot range).....	6,100 meters
Elevation corresponding to time 21.2 seconds.....	311 mils
Derived site (315 - 311).....	+ 4 mils
Vertical interval (+ 4 × 6,100) (GST)...	+ 22 meters
Altitude of registration point (assumed)...	400 meters
Altitude of battery (400 - 22).....	378 meters

484. Determination of Range and Altitude, Time Plot, Site Known

a. If an approximate site is known, the polar plot range is determined in the same manner as described in paragraph 483.

b. The known site is used to determine the altitude of the battery.

c. The elevation is derived by subtracting the known site from the adjusted quadrant elevation.

485. Determination of Site by Firing (Executive's High Burst)

An approximate site approaching survey accuracy may be determined by firing a modified high-burst registration after the completion of the precision registration.

a. Fuze setting (time), for a given charge, is a function of elevation plus the complementary angle of site. Therefore, if the fuze setting is constant but the quadrant elevation is varied, the *elevation plus comp site* to each of the resulting points of burst is constant.

b. If, after a precision registration, a group of rounds is fired with the adjusted time but with a quadrant elevation large enough to raise the point of burst so that the burst is visible from the gun position, the angle of site to the burst can be measured. The measured angle of site is subtracted from the fired quadrant elevation. The result is the elevation plus comp site to the burst (QE=elevation + angle of site + comp site). The elevation plus comp site thus determined corresponds to the fuze setting fired (adjusted time) and is equal to the elevation plus the comp site to the registration point. Subtracting the elevation plus comp site from the adjusted quadrant elevation for the registration point gives the angle of site to the registration point. The angle of site thus determined and the range corresponding to the adjusted time can be used to compute the vertical interval and the site to the registration point.

c. The procedure for conducting an executive's high burst is as follows:

- (1) After the time registration, the S3 sends the following command to the battery executive officer: OBSERVE HIGH BURST, MEASURE ANGLE OF SITE, 3 ROUNDS, ADJUSTED DEFLECTION (so much), ADJUSTED TIME (so much), ADJUSTED QUADRANT ELEVATION (so much). The executive officer estimates the increase in site necessary to cause the bursts to be visible from the battery position and adds it to the announced quadrant elevation. He then has the base piece fire three rounds at

the adjusted deflection, adjusted time, and the increased quadrant elevation. The executive officer measures the angle of site to each burst with an aiming circle or BC scope (battery commander's telescope) set up in the vicinity of the base piece. He then reports the average observed angle of site and the quadrant elevation fired.

- (2) At FDC, the site to the registration point, the adjusted elevation, and the vertical interval between the battery and the registration point are determined in the following manner:

- (a) The elevation plus comp site for the executive's high burst is determined by subtracting the average angle of site reported by the battery executive officer from the quadrant elevation fired. The elevation plus comp site thus determined is also the elevation plus comp site to the registration point.

- (b) The angle of site to the registration point is determined by subtracting the elevation plus comp site from the adjusted quadrant elevation to the registration point.

- (c) The C and D scales of the GST are used to determine the vertical interval between the battery and the registration point by multiplying the angle of site ((b) above) by the range to the registration point divided by 1,000.

- (d) Site to the registration point may then be determined by dividing the vertical interval by the range to the registration point using the appropriate site charge scale of the GST.

- (e) The adjusted elevation may be derived by subtracting the site ((d) above) from the adjusted quadrant elevation.

d. For example, a 155-mm howitzer (FT 155-Q-3) was registered on a point with charge 5. The adjusted data for the registration point

included adjusted time (fz M520), 20.4, and adjusted quadrant elevation 292 mils. The report from the executive officer following the high burst was OBSERVED ANGLE OF SITE +14; QUADRANT FIRED 315. Determination of registration point site, adjusted elevation, and vertical interval is as follows:

Range corresponding to adjusted time	
(20.4)	5910 meters
QE fired for high burst	315 mils
Average angle of site to high burst	+14 mils
Elevation plus comp site to high burst	301 mils
Adjusted QE to registration point	292 mils
Elevation plus comp site to registration point	301 mils
Angle of site to registration point	
(292-301)	-9 mils
Vertical interval (-9 × 5910/1000, C and D scales, GST)	-52 meters
Site (-52/5910, GST)	-10 mils
Adjusted elevation (292-(-) 10)	302 mils

Note. If graphical equipment is not available, site may be determined in the following manner:

Comp site factor for range 5910	
(5900)	-0.074 mils
Comp site (9 × -0.074)	-0.7 mils
Site (-9 + (-) 0.7 = -9.7)	-10 mils

e. After understanding the theory of determination of site by firing, it may be easier to use the "asked for—got" rule to compute the angle of site. Take, as an example, the problem in d above: If the angle of site to the registration point had been zero, the increase in quadrant elevation to 315 (increase of +23 mils "asked for") would have caused the bursts to occur at a measured angle of site of +23 mils. Since the bursts actually occurred at a measured angle of site of +14 mils ("got"), the registration point angle of site must be -9 mils.

The formula used is—

$$\begin{aligned} \text{Angle of site to} &= \text{"got"} \text{ minus "asked for"} \\ \text{registration point} & \\ -9 &= +14 - (+) 23 \end{aligned}$$

This angle of site must be converted to site as above.

486. Deflection Index

After the battery has been polar plotted on

the chart, a deflection index is constructed at the adjusted deflection in the usual manner.

487. GFT Settings

The GFT setting for a battery using an observed firing chart is made in the usual manner. The hairline is placed over the chart range (polar plot range). The elevation gageline (if any) is drawn through the adjusted (derived) elevation. The time gageline is drawn through the adjusted time.

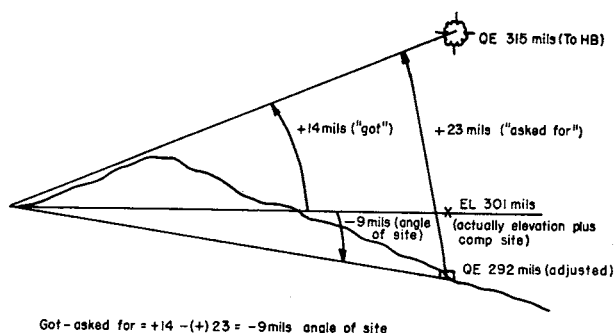


Figure 115.1. "Asked for - - - got" diagram.

Section III. BATTALION OBSERVED FIRING CHART

488. General

a. A battalion observed firing chart is based on the concept that points located with respect to a common point are located with respect to each other. If each firing battery of a battalion has registered on the same registration point and has been located on the firing chart (pars. 480-487), the batteries are then considered to be plotted in correct relationship to each other. Because the batteries are located correctly with respect to each other, the fires of the battalion may be massed on any target located by the adjustment of one of the batteries.

b. The principles involved in the construction of a battalion observed firing chart are the same as those for the construction of a battery observed firing chart. This section will describe the techniques used in the construction of the battalion chart.

489. Determination of Direction for Polar Plotting

The direction used to polar plot each battery is determined in the manner prescribed in paragraph 481.

490. Determination of Range and Altitude, Percussion Plot

a. Range and altitude for each battery may be determined in the manner described in paragraph 482.

b. If the relative altitudes of the batteries of the battalion can be determined, the accuracy

of the firing chart can be improved. One battery is selected as a reference and its polar plot range and altitude are determined in the manner described in paragraph 482. The altitude and range for each of the other batteries is determined in the following manner:

- (1) The vertical interval from the battery in question to the registration point is computed by applying the difference in altitude between the battery in question and the reference battery to the vertical interval from the reference battery to the registration point.
- (2) An apparent site for the battery in question is computed using the vertical interval ((1) above) and the range corresponding to the adjusted quadrant elevation for the battery.
- (3) An apparent adjusted elevation is derived by subtracting the apparent site from the adjusted quadrant elevation.
- (4) A new site is then computed using the vertical interval and the range corresponding to the apparent adjusted elevation, and a new adjusted elevation is determined. If the new site varies by more than 1 mil from the apparent site, successive approximation is continued until two successive sites agree, or agree within one mil.
- (5) When the apparent site agrees within 1 mil of the last site computed, determine the adjusted elevation. The polar

plot range is the range corresponding to this adjusted elevation.

c. *Example:* The batteries of a 155-mm howitzer battalion (FT 155-Q-3) have registered on a common registration point with charge 5. The assumed altitude of the registration point and Battery B, the reference battery, is 500 meters. The battery vertical intervals with reference to Battery B are: Battery A, -48 meters; Battery C, +34 meters. The adjusted data included:

Btry	Adj QE
A	337
B	323
C	320

Determine the battery altitudes and polar plot ranges as follows:

(1) *Battery B:*

Altitude of registration point	500 meters
Altitude of Battery B	500 meters
Vertical interval	Zero
Site	Zero
Adjusted elevation (323 — 0)	323 mils
Range corresponding to adjusted elevation, 323 mils (polar plot range)	6280 meters

(2) *Battery A:*

Altitude of Battery B	500 meters
Vertical interval (with respect to Battery B)	-48 meters
Altitude of Battery A	452 meters
Altitude of registration point	500 meters
Vertical interval	+48 meters
Range corresponding to adjusted quadrant elevation, 337 mils	6480 meters
1st apparent site (+48/6480, GST)	+8 mils
1st apparent adjusted elevation (337 — (+) 8)	329 mils
Range corresponding to 1st apparent adjusted elevation, 329 mils	6390 meters
2d apparent site (+48/6390, GST)	+9 mils
This site agrees within 1 mil of the last site computed; therefore, it	

is used to determine the adjusted elevation

(337 — (+) 9)	328 mils
Range corresponding to adjusted elevation, 328 mils, (polar plot range)	6350 meters
(3) <i>Battery C:</i>	
Altitude of Battery B	500 meters
Vertical interval (with respect to Battery B)	+34 meters
Altitude of Battery C	534 meters
Altitude of registration point	500 meters
Vertical interval	-34 meters
Range corresponding to adjusted quadrant elevation, 320 mils	6240 meters
1st apparent site (-34/6240, GST)	-6 mils
1st apparent adjusted elevation (320 — (-) 6)	326 mils
Range corresponding to 1st apparent adjusted elevation, 326 mils	6320 meters
2d apparent site (-34/6320, GST)	-6 mils
This site agrees with the last site computed.	
Therefore, the adjusted elevation is 326 mils.	
Range corresponding to adjusted elevation, 326 mils (polar plot range)	6320 meters

491. Determination of Range and Altitude, Time Plot

a. The range and altitude for each battery may be determined as prescribed in paragraph 483.

b. Each battery may fire an executive's high burst to determine site to the registration point (para. 485). Range altitude, and adjusted elevation are determined as prescribed in paragraph 484.

c. If the relative altitudes of the batteries are known, one battery may fire an executive's high burst to determine its site and altitude with respect to the registration point. The

altitudes of the other batteries with respect to the registration point may then be computed. Site is computed using the vertical interval between the battery and registration point and the range corresponding to the adjusted time. The adjusted elevation is derived by subtracting the site from the adjusted quadrant elevation.

d. For example, the batteries of a 155-mm howitzer battalion have registered on a common registration point with charge 5. The relative altitudes of the batteries are as follows: A, +9 meters; B, 0 meters; C, -6 meters. Assumed altitude of the registration point is 400 meters. Adjusted data are as follows:

Btry	Adjusted OE	Adj ti
A	330	21.8
B	323	21.5
C	320	21.0

Following its registration, Battery B fired an executive's high burst and determined the site to the registration to be +9 mils and the vertical interval to be +50 meters.

Btry	Range	Altitude	Site	Adj elev
A	6240	359 meters	+7	323m
B	6170	350 meters	+9m	314m
C	6050	344 meters	+10	310m

e. If the site for one battery can be determined by an executive's high burst, a common graphical firing table (GFT) setting can be constructed and used to determine the sites for the other batteries of the same caliber.

f. *Example:* The batteries of a 155-mm howitzer battalion (FT 155-Q-3) have registered on a common registration point with charge 6. The assumed altitude of the registration point is 400 meters. The adjusted data included:

Btry	Adj time	Adj QE
A	25.0	327
B	25.7	330
C	26.2	339

The site for Battery B, determined from an executive's high burst is -5 mils. Construct a common GFT setting and determine the polar plot range and altitude as follows:

(1) *Battery B:*

Adjusted quadrant elevation	330 mils
Site (executive's high burst)	-5 mils
Adjusted elevation (330—(-5))	
5)	335 mils

Range corresponding to
adjusted time, 25.7 (polar
plot range) 7990 meters
Vertical interval ($- \times 7990$,
GST) -36 meters

Note. Since a common GFT is to be used to derive site for the other batteries and the vertical intervals for these batteries will be based upon this site, the vertical interval for the battery that fires the executive's high burst is also computed using *site*, not angle of site.

Altitude of registration point 400 meters

Altitude of Battery B 436 meters

The common GFT setting constructed from this data is—

GFT B, Charge 6, Lot—,

Range 7990, Elevation 335,
Time 25.7.

(2) *Battery A.*

To derive the site for Battery A, move the hairline to the adjusted time, read the elevation under the elevation gageline of the common GFT setting, and subtract this elevation from the adjusted QE.

Adjusted time 25.0
Adjusted elevation (elevation
gageline) 324 mils
Adjusted quadrant elevation 327 mils
Site (327 — 324) +3 mils
Range corresponding to
adjusted time, 25.0 (polar
plot range) 7820 meters
Vertical interval ($+3 \times 7820$,
GST) +21 meters
Altitude of registration point 400 meters
Altitude of Battery A 379 meters

(3) *Battery C:*

Adjusted time 26.2
Adjusted elevation (elevation
gageline) 342 mils
Adjusted quadrant elevation 339 mils
Site (339 — 342) -3 mils
Range corresponding to
adjusted time, 26.2 (polar
plot range) 8100 meters
Vertical interval (-3×8100 ,
GST) 22 meters
Altitude of registration point 400 meters
Altitude of Battery C 422 meters

Btry	Range	Altitude	Site	Adj elev
A	6240	359 meters	+7	323m
B	6170	350 meters	+9m	314m
C	6050	344 meters	+10	310m

Section IV. OBSERVED FIRING CHART FOR MORE THAN ONE BATTALION

492. General

Massing of fires of more than one battalion by using an observed firing chart is possible provided common control can be established. To achieve common control, aiming circles must be uniformly declinated. A common registration point with coordinates and altitude assigned must be designated for all battalions. Also, one battery of each battalion must be registered on the common registration point. The area in which fires can be accurately massed is smaller than the area represented by the observed firing chart for one battalion. The comparatively large distance between battalions will introduce errors which increase as the distance from the common registration point to the target increases. Relative altitudes of the common registration point and battalion position areas must be known if several widespread battalions are to mass their fires effectively.

493. Construction of Observed Firing Chart for More Than One Battalion (Plotting)

Higher headquarters is responsible for selecting the registration point, assigning arbitrary coordinates and altitude, and coordinating registration. Registration may be coordinated by assigning times for conducting registrations or by requiring a single battalion to register one battery of its own and one battery from each of the other battalions involved. Each battalion observed firing chart is constructed as follows (fig. 116):

a. The adjusting battery is polar plotted from the common registration point designated by higher headquarters. The back azimuth of the adjusted azimuth and distance derived from the adjusted data are used in polar plotting.

b. The battalion registration point is polar plotted from the adjusting battery position. The azimuth and distance (to the battalion registration point) that were determined previously

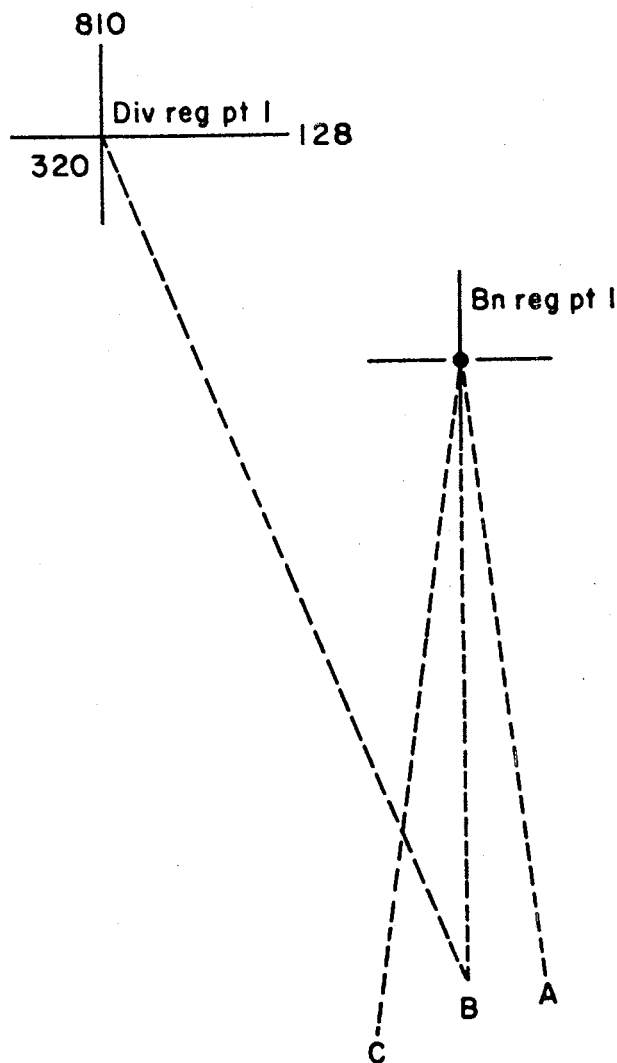


Figure 116. Battalion observed firing chart based on registration on a division artillery registration point.

from registration on the battalion registration point are used in polar plotting.

c. Other batteries of the battalion are then polar plotted from the battalion registration point in the normal manner.

d. If the battalion registration point and the common registration point are not within transfer limits or if different charges are used, then

separate GFT settings and separate deflection correction scales will be established.

494. Construction of Observed Firing Chart for More Than One Battalion (Tracing Paper Method)

An alternate, but less accurate, method of constructing an observed firing chart for more than one battalion is the *tracing paper method*. The chart is constructed as follows:

a. The battalion observed firing chart has been constructed. The battalion registration point, batteries, and fired concentrations are plotted on the battalion chart. After registration, the common registration point is polar plotted from the adjusting battery on the battalion chart. The altitude of the common registration point is computed.

b. An overlay of the battalion chart is made. The overlay includes all points plotted on the battalion chart.

c. The common registration point is plotted

on the chart for more than one battalion at the coordinates specified by division artillery or group headquarters.

d. A ray is drawn on the chart for more than one battalion in the direction of the back azimuth of the adjusted azimuth from the registration on the common registration point.

e. The overlay is then placed over the chart for more than one battalion and is oriented so that the common registration point is placed over its chart location and the registering battery is over the ray previously drawn (d above).

f. The location of batteries, battalion registration point, and concentrations are pinpricked through the overlay onto the chart for more than one battalion.

g. All altitudes are reconciled with the altitude assigned to the common registration point.

h. Deflection indexes are constructed on the chart for more than one battalion. The indexes are based on adjusted data for the battalion chart.

Section V. OBSERVED FIRING CHART WITH INCOMPLETE SURVEY

495. General

a. A position area survey may sometimes be used in conjunction with the observed firing chart until the surveyed firing chart is available. That part of the chart established by firing must be plotted to the same scale as that part obtained by survey.

b. Typical situations which might necessitate the use of an observed firing chart based on registration of one battery and a position area survey are—

- (1) When lack of time or ammunition precludes registering all three batteries.
- (2) When the battalion displaces by echelon. Data can be ready for the remaining batteries when they arrive at the new position.
- (3) When displacement of the battalion is to be made after dark. A single howitzer can be brought up and registered during daylight. Data can be ready for the entire battalion when it arrives.
- (4) When alternate positions have been occupied and firing must begin without registration from those positions.

- (5) When fire from positions to be occupied is not permitted before a certain hour but massing is required immediately after that time, a single registration may be performed from an alternate position. Data can then be prepared for the battery positions after connecting them to the registration position with a position area survey.

496. Procedure for Construction of Observed Firing Chart, Position Area Survey Only

The procedure for the construction of a battalion observed firing chart based on the registration of one battery and a position area survey is as follows:

a. A common orienting line (OL) is established for the battalion, if possible; otherwise, an OL is established for each battery.

b. Starting from any convenient point, a traverse is run to locate all battery positions horizontally and vertically with respect to each

other and to establish common directional control for all orienting lines.

c. The battery positions, altitudes, and OL's are plotted on tracing paper to the same scale as that for the chart to be used. This overlay, including the measured grid azimuth of the OL's, constitutes the position area survey as delivered to the fire direction center.

d. One battery is registered on the registration point; from the adjusted data, the observed firing chart is started by plotting the registration point and back plotting the registering battery.

e. The azimuth of fire derived from the measured orienting angle of the registering battery

is used for the direction of fire line of the battery on the overlay of the position area survey.

f. The battery center plotted on the overlay is placed over the registering battery center on the firing chart. The overlay is rotated until the direction of fire line on the chart and the overlay coincide. The locations of the nonregistering batteries are pinpricked and then labeled with proper altitudes in relation to the registering battery.

g. The azimuth from each nonregistering battery to the registration point is measured. For each battery, the azimuth of the battery OL minus the determined direction of fire equals the orienting angle for laying the battery.

Section VI. RADAR FIRING CHARTS

497. General

In conjunction with radar observed high-burst registrations, there are three techniques that can be used in constructing a firing chart. The techniques are as follows:

a. Observed firing chart improved by radar (time plot).

b. Radar chart, no maps or survey.

c. Radar chart, relative location of registering piece and radar determined.

498. Time Plot Observed Firing Chart Improved by Radar

In most cases the radar is in position and ready to observe by the time the firing batteries have completed registration. The time plot chart improved by radar may be constructed as soon as the registration of all batteries and a radar observed high-burst registration by one of the batteries are completed. The radar will supply data for an accurate GFT setting and deflection correction. The observed firing chart, time plot, improved by radar is the most accurate type of observed firing chart that can be constructed. Construction of a firing chart must not be delayed to await the availability of a radar.

499. Advantages of Radar Improved Chart

The radar improved chart has the following advantages over an observed firing chart, time plot:

a. An accurate range and vertical interval can be obtained from the radar location of the high-burst. An accurate site can be determined and then subtracted from the quadrant elevation fired to derive an accurate adjusted elevation. The GFT setting, derived from the radar observed high-burst registration, when applied to the adjusted data from the precision registrations on the registration point, will allow the accurate determination of polar plot range and altitude.

b. The direction in which the batteries are polar plotted from the registration point is improved by the amount of the deflection correction determined from the radar observed high-burst registration.

500. Procedure for Construction of Radar Improved Chart

a. All batteries are registered on a common registration point to determine, an adjusted deflection, an adjusted azimuth or orienting angle, an adjusted time, and an adjusted quadrant elevation.

b. The radar is located with respect to one battery by survey and the locations of the battery and radar are plotted on a firing chart. The battery fires a high-burst registration observed by the radar. The point selected for the high burst should be—

- (1) Visible to the radar.
- (2) As close as possible to the common registration point.

(3) Low enough that the site is less than 50 mils.

c. The radar section will provide the direction, distance, and vertical interval from the radar to the high-burst location.

d. The high-burst location is polar plotted from the radar on the chart.

e. Chart data (deflection, range, site) is then determined from the battery to the high-burst location.

f. The GFT setting is determined. GFT setting range is the chart range (*e* above). The adjusted elevation is the quadrant elevation used to fire the radar observed high-burst registration minus the site (*e* above). The adjusted time is the fuze setting used to fire the radar observed high-burst registration.

g. The deflection correction is computed by subtracting the chart deflection (*c* above) from the deflection used to fire the radar observed high-burst registration.

h. The common registration point is plotted at assumed coordinates on another chart and assigned an assumed altitude. The batteries will be polar plotted from the common registration point.

i. The polar plot direction is determined as follows:

- (1) The direction of fire is determined in the normal manner (par. 481).
- (2) The deflection correction (*g* above) is subtracted from (1) above.
- (3) The polar plot direction is the back azimuth of (2) above.

j. The polar plot range is determined by using the GFT setting from the radar observed high-burst registration. The time gageline is placed over the adjusted time to the registration point and the range is read under the hairline.

k. With the time gageline over the adjusted time, the adjusted elevation to the registration point is read under the elevation gageline. The site to the registration point is determined by subtracting the derived adjusted elevation from the adjusted quadrant elevation. The vertical interval and altitude of the battery are computed.

l. The deflection index is constructed at the adjusted deflection.

m. The GFT setting from the radar observed high-burst registration is used for all firing from the radar improved charts.

n. For example, all batteries of a 155-mm howitzer battalion have registered on a common registration point (assumed altitude 400 meters) with charge 5, lot WZ. Adjusted data are shown below.

Btry	Adj az	Adj df	Adj QE	Adj ti
A	6046	2751	280	18.8
B	6134	2766	274	18.4
C	6229	2771	269	18.0

- (1) A traverse is run between the radar antenna and the base piece of Battery B. The locations of the radar antenna and Battery B are plotted on a firing chart. The radar is 6 meters above the base piece of Battery B.
- (2) Battery B fires a high-burst registration over the registration point with the following data: charge 5, lot WZ, deflection 2,766, time 18.4, quadrant 287.
- (3) The radar section reports the data to the high-burst location as range 4,360 meters, azimuth 6,074 mils, vertical angle +17 mils. The high-burst location is polar plotted from the radar. The high-burst location is 73 meters above the radar (GST: 4,360 x (+17)).
- (4) Chart data from Battery B to the high-burst location are measured as deflection 2,781 mils, range 5,320 meters.
- (5) The GFT setting is determined as follows:

Height of HB with respect to radar	+73 meters
Height of radar with respect to Btry B	+6 meters
Height of HB with respect to Btry B	+79 meters
Chart range, Btry B to HB	5,320 meters
Site, Btry B to HB (GST: chg 5; +79.5,320)	+16
Adjusted elevation (287 - 16)	271 mils

GFT B: charge 5, lot
WZ, range 5,320, elevation 271, time 18.4

- (6) The deflection correction is determined as follows:

Chart deflection, Btry	
B to HB	2,781 mils
Fired deflection	2,766 mils
Deflection correction	R15 mils

- (7) The polar plot data are computed using the GFT setting ((5) above), the deflection correction ((6) above), and the adjusted data from the common registration point.

Element	Battery		
	A	B	C
Adjusted azimuth to registration point.....	6046	6134	6229
Deflection correction.....	R15	R15	R15
Corrected azimuth to registration point.....	6031	6119	6214
Polar plot azimuth.....	2831	2919	3014
Range (corresponding to adj ti).....	5420	5320	5220
Elevation.....	277	271	265
Adjusted quadrant elevation.....	280	274	269
Site (adj QE-E1).....	+3	+3	+4
Vertical interval.....	+15	+15	+19
Altitude.....	385	385	381
Deflection index constructed at deflection.....	2751	2766	2771

501. Radar Chart

Without radar, there is no easy and practical method by which a battalion can occupy positions during darkness without maps or prior survey and be prepared to mass effective fires at daylight. However, when radar is available, an observed firing chart can be constructed which will permit the battalion to mass fire effectively. This observed firing chart is called the *radar chart*.

502. Construction of Radar Chart

The radar chart is not as accurate as an observed firing chart improved by radar. Its construction is based on the firing of a high-burst registration by each battery. Procedures for construction of the radar chart are as follows:

a. The radar is oriented by using the aiming circle and is plotted on the firing chart at assumed coordinates and altitude.

b. Batteries are laid by azimuth on the approximate azimuth to the center of the sector.

c. A high-burst registration, observed by radar, is fired from the base piece of each battery at a safe range and fuze setting.

d. Range, azimuth, and vertical angle to each of the three high-bursts are determined by radar.

e. Each high-burst is polar plotted on the firing chart with respect to the radar.

f. The altitude of each high-burst is determined by using the radar range and vertical angle.

g. Each battery is back plotted on the chart from its high-burst location.

- (1) Each high-burst represents the registration point of the battery which fired it.

- (2) The battery is polar plotted from its high-burst location on the back azimuth of the azimuth at which the high-burst was fired.

- (3) The range at which the battery is plotted is the range corresponding to the fuze setting (minus fuze correction, if known) with which the high-burst was fired.

h. The altitude of the battery is equal to the altitude of its high-burst minus the vertical interval between the battery and the high-burst. The vertical interval is determined by multiplying the derived site by the range at which the battery is plotted (GST).

i. The deflection index is constructed for each battery in the usual manner.

503. Evaluation of Radar Chart

The radar chart is fundamentally a time plot observed firing chart, sites unknown, with the exception that each battery has its own registration point. The accuracy of the radar chart is slightly less than that of the time plot observed firing chart, sites unknown.

a. To obtain the greatest accuracy and to attain usable battalion transfer limits, the three high-burst registrations should be fired as close to the same point as possible.

b. Without survey, pointing data for the radar to each of the high-bursts cannot be determined accurately. For this reason, it will generally be necessary to move the antenna in azimuth and elevation after the first round is

fired in order to observe succeeding rounds through the orienting telescope. Therefore, each registration will usually require seven to eight rounds.

c. The radar chart can be used to mass fires on targets reported by radar and on targets which have been adjusted on by one battery.

504. Radar Chart, Registering Piece Located

If the relative location of the radar and the registering piece can be established either by survey or by moving the registering piece to the radar, the accuracy of the radar chart can be substantially improved, since a GFT setting and deflection correction can be established.

a. When one battery position is located in relation to radar after a radar chart without survey or maps has been constructed, a GFT

setting and deflection correction can be derived from the registration of that battery. When a registering piece is moved to the radar position, another high-burst registration must be fired to establish a GFT setting and deflection correction.

b. When radar is located relative to one battery prior to initial registration, the high-burst registration of this battery is used to establish the GFT setting and deflection correction.

c. The GFT setting and deflection correction in *a* and *b* above are established and applied in back plotting each battery from its respective high-burst location in the same manner as for an observed firing chart improved by radar. However, the chart thus established is not as accurate as the observed firing chart improved by radar, since the high bursts are not at a common point.

Section VII. TRANSFER FROM OBSERVED FIRING CHART TO SURVEYED FIRING CHART

505. General

As soon as the surveyed firing chart is available, it should replace the observed firing chart. The observed firing chart is retained until all concentrations are transferred to the surveyed firing chart. The transfer of information is made as soon as possible.

506. GFT Settings and Deflection Index

a. The determination of GFT settings and construction of the deflection index for the surveyed firing chart are accomplished in the same manner as they would have been if the surveyed firing chart had been on hand at the time the registrations were fired. The adjusted elevation is determined by subtracting the site, as computed from the surveyed firing chart, from the adjusted quadrant elevation. The range is measured on the surveyed firing chart. The time gage line is drawn over the adjusted time for each registration. When all three batteries have registered on the observed firing chart, each may have a different GFT setting.

b. The deflection correction scale to be used with the surveyed firing chart is based on the

survey chart GFT setting with a deflection correction of zero at registration point range.

507. Transfer From Observed Firing Chart to Surveyed Firing Chart, Percussion Fuze

a. The procedure for transfer of targets from the observed to the surveyed firing chart is the same as that for replotting observed targets on the surveyed firing chart (para. 416). Data for replot of a target are obtained from the adjusted data for that target. (Determination of adjusted data and replot data is discussed in para. 509 and 510.)

- (1) The target is plotted on the surveyed firing chart using the FFE chart deflection from the observed firing chart.
- (2) If a map is not available, any information indicating the altitude of the target such as the observer's UP or DOWN correction, is used to determine the vertical interval. Successive approximation is required in order to

determine site and the adjusted elevation (para. 509e).

- (3) The surveyed firing chart GFT setting is used to derive the range from the adjusted elevation.

b. When more than one registration has been made, the elevation used in establishing the GFT setting is selected from the registration which most nearly coincides with the time of firing on the targets.

508. Transfer From Observed Firing Chart to Surveyed Firing Chart, Time Fuze

Targets fired with time fuze are transferred from the observed firing chart to the surveyed firing chart in the same manner as those fired with percussion fuze, except for the following:

a. The relationship between range, adjusted time, and adjusted elevation is fixed by the surveyed firing chart GFT setting.

b. The time gageline is placed over the adjusted time. Range is read under the hairline and the adjusted elevation is read under the elevation gageline.

c. The adjusted elevation is subtracted from the quadrant elevation (minus 20/R at fire for effect range) to determine the site.

509. Transfer to Surveyed Firing Chart, Computer Records Available

When the computer's records are available, targets are replotted on the surveyed firing chart by polar plotting at deflections, ranges, and altitudes as described below.

a. *Deflection.* The same deflection used to replot the target on the observed firing chart is used to replot that target on the surveyed firing chart. The replot deflection is the final chart deflection as recorded on the FDC Computer's Record (DA Form 6-16). Using this deflection may introduce an error owing to the difference in deflection correction scales of the two charts, but the error will seldom exceed 1 mil.

b. *Range.* Range is determined with the GFT setting for the surveyed firing chart. For missions fired with percussion fuze, range is determined by placing the elevation gageline over the adjusted elevation and reading the range under the hairline. For missions fired with time fuze, the time gageline is placed over the adjusted time setting and the range is read under the hairline.

c. *Site and Elevation (Percussion Fuze).*

- (1) The altitude of the target is determined from a map or from the observer's request. For example, the observer requested FROM REGISTRATION POINT, RIGHT 350, UP 20, ADD 400. The target is 20 meters above the registration point.

- (2) The site is determined by successive approximation. Site is based on the vertical interval (difference in altitude of battery and target) and fire for effect range.

- (3) The final adjusted elevation is used to determine the final plot range.

d. *Site and Elevation (Time Fuze).*

- (1) If accurate sites were known for the observed firing chart GFT settings, the same sites and elevations will be applied to the surveyed firing chart.

- (2) If accurate sites were not known for the observed firing chart GFT setting, the fuze correction will be the same in the surveyed firing chart GFT setting. The adjusted elevation must be obtained for each target. It is obtained by placing the surveyed GFT setting time gageline over the adjusted time and reading the elevation under the elevation gageline. The site is derived by subtracting the elevation from the adjusted quadrant elevation (minus 20/R at fire for effect range).

e. *Example of Target Replotted on a Surveyed Firing Chart.* Personnel from an 8-inch howitzer battalion have completed survey and are transferring targets from an observed firing chart (percussion fuze) to a surveyed firing chart. Surveyed firing chart GFT setting: *GFT B: charge 5, lot XT, range 7070, elevation 310.* Concentration BC401 is to be replotted on the surveyed firing chart. No map is available.

Fire for effect data				Data from computer's record
Fz	DF	Range	QE	Observer's site corr
Q	2,616	7400	354	From reg pt 1 Up 70
Altitude of battery	-----			= 420 meters
Altitude of registration point (survey)	-----			= 438 meters
Altitude of concentration (438+70)	-----			= 508 meters
Vertical interval	-----			= +88 meters
Apparent site of concentration (GST)	-----			
(88/7,400)	-----			= +13 mils
Quadrant elevation fired	-----			= 354 mils
Apparent adjusted elevation (354-	-----			
(+13))	-----			= 341 mils
Apparent range for replot (GFT)	-----			= 7,580 meters
Site (GST) (88/7,580)	-----			= +13 mils*
Range for replot (elevation 341)	-----			= 7,580 meters

*Agrees with apparent site within 1 mil.

510. Transfer to Surveyed Firing Chart, Computer Records Not Available

When the computer records are not available, targets are replotted on the surveyed firing chart by polar plotting at deflection, range, and altitude determined as described below.

a. Deflection. The deflection for replot of a target is measured directly from the observed firing chart. It is used without change in transferring to the surveyed firing chart, since the

deflection correction for the surveyed firing chart will not differ from that for the observed firing chart by more than 1 mil.

b. Range. The range is measured from the observed firing chart. The elevation that was fired is determined by using the observed firing chart GFT setting. The range for replotting the target on the surveyed firing chart is determined by using this elevation as shown in paragraph 509.

c. Site. Site is determined as described in paragraphs 508 and 509.

PART FIVE MISCELLANEOUS

CHAPTER 27 INTERIOR BALLISTICS

Section I. PROPELLANTS AND MUZZLE VELOCITY

511. Introduction

Interior ballistics is the science which deals with the factors affecting the motion of projectiles before they leave the muzzle of the piece. The total effect of all interior ballistic factors determines the velocity with which the projectile leaves the muzzle. This velocity is called the muzzle velocity and is expressed in feet or meters per second. Actual measurements of the muzzle velocity of a series of rounds, corrected for extraneous factors, depict the performance of a certain weapon-ammunition combination. The result of these measurements can be compared with the standard velocities listed in the firing table for the charge fired in order to obtain the variation from standard. Application of corrections to compensate for nonstandard muzzle velocity is one of the most important elements in preparation of accurate firing data (fig. 116.1).

512. Nature of Propellants and Projectile Movement

a. A propellant is a low-order explosive which burns rather than detonates. In artillery cannons using separate loading ammunition, the propellant is burned in a chamber defined by the powder chamber and the base of the projectile; in cannons using fixed and semifixed ammunition, the propellant is burned in a chamber defined by the shell case and the base of the projectile. When the gases generated by the burning propellant develop pressure sufficient to overcome initial bore resistance, the projectile starts its forward motion.

b. The gas pressure builds up quickly to a peak and gradually subsides shortly after the start of projectile movement. The peak pressure, together with the travel of the projectile in the bore (pressure-travel curve), determines the speed at which the projectile leaves the tube (fig. 116.1).

c. A few general rules ((1)-(5) below) will assist in understanding how various factors affect velocity performance of a weapon-ammunition combination.

- (1) An increase in the rate of burning of a propellant increases resultant gas pressure.
- (2) An increase in the size of the powder chamber without a corresponding increase in the amount of propellant decreases gas pressure.
- (3) Gas escaping around the projectile in the tube decreases pressure.
- (4) An increase in bore resistance to projectile movement before peak pressure further increases pressure.
- (5) An increase in bore resistance at any time has a dragging effect on the projectile and decreases velocity. Temporary variations in bore resistance are caused by extraneous deposits in tubes and on projectiles and by differences in heat between the inner and outer surfaces of the tube.

513. Standard Muzzle Velocity

a. Appropriate firing tables give the standard value of muzzle velocity for each charge. These

standard values are based on an assumed standard tube. The standard values are points of departure, not absolute standards, since they cannot be reproduced at a given instance; that is, a specific weapon-ammunition combination cannot be selected with the knowledge that it will result in a standard muzzle velocity when fired.

b. Charge velocities are established indirectly by the military characteristics of a weapon. Cannons capable of high-angle fire (mortars and howitzers) require a greater choice in number of charges than do cannons capable of low-angle fire only (guns). This greater choice is needed in order to achieve range overlap between charges in high-angle fire and the desired range-trajectory combination in low-angle fire. Other factors considered are the maximum range specified for the weapon and the maximum elevation and charge (with resulting maximum pressure) which the weapon can accommodate.

c. Manufacturing specifications for ammunition include the required velocity performance within certain tolerances. The ammunition lots

are subjected to firing tests which include measuring the performance of the lots tested against the concurrent performance of a control or reference lot. Both the control lot and the lot being tested are fired through the same tube, assuming that whatever the characteristics of that tube, the performance of both lots is influenced identically. The foregoing assumptions, although accurate enough for firing tests, are not entirely correct and allow a certain amount of error in propellant assessment procedures. (Assessment procedures include correcting charge weights for the tested lot to match the velocity developed by the control lot during the test.) Therefore, a wide variation in the performance of ammunition under field conditions can be expected even though quality control over manufacture is exercised. Also, if a cannon develops a muzzle velocity 10 feet per second faster (or slower) than another weapon with the same charge lot, it will not necessarily do the same with any other charge of any other lot. However, weapon-ammunition performance is not so unstable that the prediction of future performance based on past results should not be attempted.

Section II. FACTORS CAUSING NONSTANDARD MUZZLE VELOCITY

514. General

In gunnery techniques, nonstandard velocity is expressed as a variation (plus or minus so many feet or meters per second) from an accepted standard. Round-to-round corrections for dispersion cannot be made. In the discussion in paragraphs 515 through 529 each factor is treated as a single entity assuming no influence from related factors.

515. Velocity Trends

Not all rounds of a series fired from the same weapon using the same ammunition lot will develop the same muzzle velocity. The variations in muzzle velocity follow a normal probability distribution about the average muzzle velocity. This phenomenon is called velocity dispersion. Under most conditions, the first few rounds follow a somewhat regular pattern rather than the random pattern associated with normal dis-

persion. This phenomenon is called velocity trend. The magnitude and extent (number of rounds) of velocity trends vary with the cannon, charge, tube condition at round 1, and firing preceding round 1. Velocity trends cannot be accurately predicted; therefore, any attempt to correct for the effect of a velocity trend is impractical. Characteristic velocity trends for some weapons, however, can be detected. A comparison of velocity trends for a 105-mm howitzer when a series of rounds is fired starting with an oily tube, a tube cleaned with rags only, and a tube cleaned with soap and water is shown in figure 117. As a general rule, the magnitude and duration of velocity trends can be minimized when firing is started with a tube which is clean and completely free of oil.

516. Ammunition Lots

Each lot of ammunition has its own mean performance level when related to a common

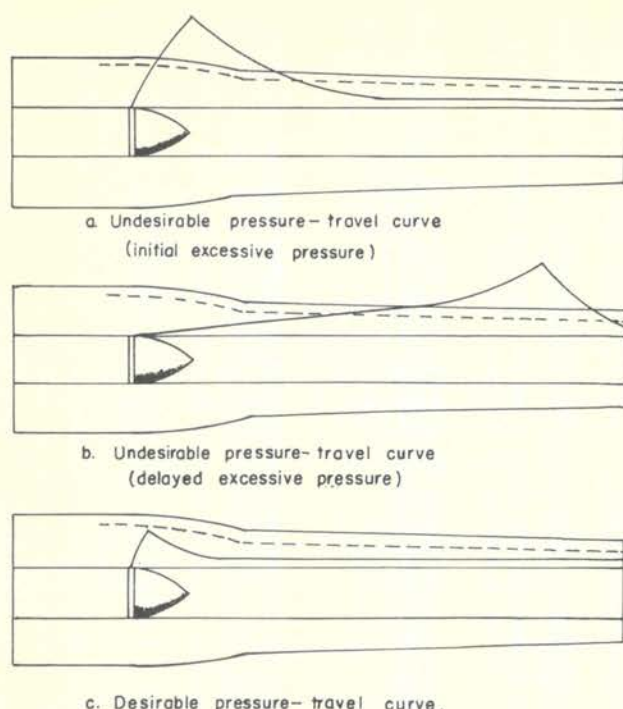


Figure 116.1. Pressure travel curves.

tube. Although the round-to-round probable error within each lot is about the same, the mean velocity developed by one lot may be much higher or lower than another lot. With separate-loading ammunition, both the propellant and the projectile lots must be identified. Variations in projectile manufacture, e.g., the diameter and hardness of the rotating band, affect muzzle velocity. (Projectile variations have a much more apparent effect on exterior ballistics.) Therefore, lots must be segregated. The result of mixing lots is increased dispersion within a series of rounds and increased miss distances of the centers of impact.

517. Tolerances in New Weapons

All new cannons of a given caliber and model will not necessarily develop the same muzzle velocity. In a new tube, the predominant factors are variations in the powder chamber and the interior dimensions of the bore. If a battalion armed with new cannons fired all of them with a common lot of ammunition, a velocity

spread of 12 feet per second between the cannon with the highest muzzle velocity and the one with the lowest muzzle velocity would not be unusual. Therefore, cannons must be calibrated even though they are new.

518. Wear of Tube

Continued firing of a cannon wears away portions of the bore by the action of heated gases, chemical action, and movement of the projectile. These erosive actions are more pronounced when higher charges are being fired. Increased tube wear tends to decrease muzzle velocity by allowing the projectile to be seated farther forward in the tube and thereby allowing more room for expanding gases, by allowing the expanding gases to escape past the rotating band, and by decreasing resistance to initial projectile movement which lessens pressure buildup. Although normal wear cannot be prevented, it can be minimized by careful selection of the charge and proper cleaning of both weapon and ammunition. Calibration data must be kept current, since losses in velocity do not uniformly follow an increase in measured wear.

519. Nonuniform Ramming

Although a weak ram would decrease the volume of the powder chamber and thereby theoretically increase the push given the projectile (the pressure of a gas varies inversely with the volume), this is only a partial effect. Improper seating of the projectile, as a result of weak ramming, allows some of the expanding gases to escape without doing any work, and a lower velocity results. The combined effect of escaping gases and a smaller powder chamber is hard to predict. Weak, nonuniform ramming produces an increase in the dispersion pattern. Hard uniform ramming is required for all rounds. When fixed and semifixed ammunition are being fired, the principles of varying volume powder chamber and escape of gases still apply, especially in worn tubes. Since the obturation of the cartridge case serves as the gas check to the rear in fixed and semifixed ammunition, proper handling and seating of the case is important in reducing escape of gases.

520. Rotating Bands

Ideal rotating bands allow proper seating, provide obturation, create proper resistance to initial projectile movement to allow uniform pressure buildup, and also provide a minimum dragging effect on the projectile once motion has started. Dirt or burrs on the rotating band cause improper seating which increases tube wear and contributes to velocity dispersion. If excessively worn, the bands may not sufficiently engage the rotating bands to impart proper spin to the projectile. Insufficient spin reduces projectile stability in flight and can result in dangerously short, erratic rounds. When erratic rounds occur or excessive tube wear is noted, ordnance ballistic and technical service teams should be called upon to determine the serviceability of each tube by wear measurements and other checks.

521. Powder Temperature (Propellant Temperature)

Any combustible material burns more rapidly when it is heated prior to ignition. When a propellant burns more rapidly, the resultant pressure on the projectile is greater and muzzle velocity is increased. The firing tables show the magnitude of this change in a table titled "Corrections to Muzzle Velocity for Propellant Temperature." Appropriate corrections to firing data can be computed from that table; however, such corrections are valid only as they reflect the true powder temperature. The temperature of propellants in sealed packing cases remains fairly uniform, though not necessarily standard (70° F.). Once the propellant is unpacked, its temperature tends to approach the prevailing air temperature. The time and type of exposure to weather result in powder temperature variations between rounds as well as mean powder temperature variations between gun sections.

It is not practical to measure powder temperature and apply corrections for each round fired by each cannon. Positive action must be taken to maintain uniform powder temperatures; failure to do so results in erratic firing. Also, the effect of a sudden change in powder temperature can invalidate even the most recent registration correction.

a. Ready ammunition should be kept off the ground; should be protected from dirt, moisture, and the direct rays of the sun; and should have an air space between the ammunition and protective covering. This procedure allows propellants to approach atmospheric temperature at a uniform rate.

b. Rounds should be unpacked sufficiently in advance so that it is never necessary during the same mission to mix freshly unpacked ammunition with ammunition which has been opened for some time.

c. Rounds should be fired in the same order as they are unpacked.

d. Propellant temperatures of ready ammunition should be taken at random points in the ammunition stack and checked periodically at intervals dependent on the changes in ambient temperature. The rounds so checked should not be removed from the rest of the ammunition but should be measured in place to get a true mean. The thermometer should penetrate the charge that is being used and must not touch any metal.

522. Moisture Content of Powder

Handling and storage can cause changes in the moisture content of powder which will affect the velocity. The moisture content of powder cannot be measured or corrected for so it is important that ammunition is provided maximum protection from the elements.

523. Position of Bagged Propellant in Chamber

In fixed and semifixed ammunition, the propellant has a relatively fixed position with respect to the chamber—the chamber being, in effect, the cartridge case. The position of separate-loading propellants, however, depends on how the cannoneer inserts the charge. The farther forward in the chamber the propellant is placed, the slower the rate of burning and the lower the subsequent velocity. In order to assure uniform positioning and thus to obtain uniform propellant performance, the base of the powder bag should be flush against the mushroom head at the instant of firing. Variations in the diameters of the bags also affect propellant performance. An increase in the bag diameter for the same amount of powder tends to increase the rate of burning and the resultant velocity. Loose tie straps or wrappings have the effect of increasing bag diameter from the original diameter; therefore, cannoneers should check wrappings for tightness even when the full charge is being used.

524. Weight of Projectile

The weight of like projectiles varies within certain weight zones. The appropriate weight zone is stenciled on the projectile. Some projectiles are not grouped in weight zones but are marked with the weight in pounds. A heavier than standard projectile is harder to push throughout the length of the tube and a decreased velocity results, whereas a lighter projectile is easier to push throughout the length of the tube and a higher velocity results. (Weight of projectile is also a factor in exterior ballistics.)

525. Coppering

When projectile velocity in the bore is high enough, sufficient friction is developed to remove the outside surface of the rotating band. The removed metal is deposited as a thin film of copper in the bore. This condition is known as coppering. It is more pronounced in high velocity weapons and high charges. The amount of copper deposited varies with the velocity. Firing with lower charges will reduce coppering. Slight coppering, such as that resulting

from firing a few rounds at the higher charges with a howitzer, tends to increase muzzle velocity; excessive coppering causes erratic velocity performance by varying the resistance of the bore to projectile movement. The removal of excessive copper is an ordnance function.

526. Powder Residues

Residues from the burned powder and certain chemical agents mixed with the expanding gases are deposited on the bore surface in a manner similar to coppering. Unless the tube is properly cleaned and cared for, these residues aggravate subsequent tube wear by causing pitting and augmenting the abrasive action of the projectile. Cleaning the tube between missions should be avoided when optimum accuracy is desired, such as for unobserved fires (par. 527h).

527. Tube Conditioning

The heat of the tube has a direct bearing on the developed velocity. For example, a cold tube offers a different resistance to projectile movement than a warm tube. A cold tube is less susceptible to coppering even at high velocities. The results of the warmup process can appear as a trend of increasing or decreasing velocities depending on the weapon, charge, oiliness of the tube, and the degree of coppering.

a. Ammunition is tested in tubes which have been thoroughly conditioned to a desired velocity level by firing several warmup rounds. Tubes which are not conditioned will not allow propellants to perform as they did when tested. Also, the round-to-round variation is much greater during the conditioning period.

b. The adjusted data and corresponding registration corrections may or may not be determined at the velocity level to be experienced later when transfers are made. For a specific projectile lot, transfers fired with velocity levels higher than the velocity levels existing at the time that corrections were determined will result in bursts beyond the target. Conversely, transfers fired with lower velocity levels will result in bursts short of the target.

c. If the velocity for a certain weapon-ammunition combination is at its true level only after sustained fire at a specified rate of fire, either increases in the rate of fire or lulls in

firing can upset this true level. A change of charge can have a noticeable effect on velocity level. For example, if a 105-mm howitzer is conditioned (brought to the true velocity level) with charge 7 (MV 1525), it will be slightly overconditioned for charge 4 (MV 860). Also, if firing is performed immediately with the lower charge, a tendency toward higher than normal velocities will be experienced on the first one or two rounds. Going from a lower to a higher charge also introduces the possibility that the first one or two rounds will have a lower than normal velocity. It is doubtful whether or not the firing with the lowest charge only can truly condition a tube to normal operating velocity levels since the warming up process is so slow at low velocities. For example, for the 105-mm howitzer, firing started with charge 3 has resulted in an average variation from standard velocity of 10 to 15 feet per second less than when firing with charge 3 was preceded by firing with charge 7. The tactical situation seldom allows the firing of conditioning rounds. However, the lack of tube conditioning is a factor that the S3 must consider in attacking targets without adjustment or in firing close to friendly troops. Likewise, possible velocity trends should be considered in center-of-impact and high-burst registrations and in calibration firing.

d. In general, tube conditioning involves two different effects. One effect is that of heating the tube until the temperature differential from inner to outer surface is stabilized at the rate of fire and charge to be used. The other effect is that of bringing the bore resistance from coppering and powder residues to a similar stabilized condition at the rate of fire and charge to be used. The first few rounds show the greatest difference from the intended level. However, these are the very rounds that determine the accuracy of fire for effect missions. It is not possible at the present time to include corrections for these trends in firing data. It may never prove feasible to include such corrections for most cannons because of the many variations between the conditioned and the unconditioned tube.

e. In calibration shoots involving more than one charge, the higher charge is fired first, since conditioning occurs with fewer rounds if rounds are fired at the highest velocity. Two to four rounds should be sufficient when the highest charge is fired; however, the observed results are the only valid criteria. Calibrations conducted with the lower charges of the 105-mm, 155-mm, and 8-inch howitzers without prior conditioning with higher charges will require relatively more rounds to reach a conditioned tube status.

f. If conditioning has been accomplished with one charge and a change to another charge is required, at least one conditioning round should be fired with the new charge.

g. Guns are more sensitive to changes in the rate of fire than howitzers. The accuracy of intensive preparation fires is adversely affected by rapid firing followed by intermittent lulls of varying length.

h. The previous conditioning of any weapon is affected by lulls in firing and ambient air temperature. If the lull is no longer than 1 hour, normally the firing of one round brings cannons to the previous velocity level. If the tubes are cleaned during relatively short lulls, erratic velocities may be experienced for the first few rounds after cleaning. If the cleaning is accomplished during long lulls, the normal velocity trends previously described may be expected. In extremely cold temperatures, the conditioning of the tube is destroyed during lulls in firing more quickly than in warm temperatures. During cold weather, more rounds may be necessary to bring the cannon to the proper velocity level.

i. Oil or moisture in the tube or on the rotating band tends to increase velocity of the particular round by causing a better initial gas seal and reducing projectile friction on the bore surface. The oily tube condition usually exists concurrently with the cold tube condition. Hence the high velocities induced by oil combining with the erratic velocities characteristic of a cold tube complicate normal velocity trends. When these factors are coupled with coppering

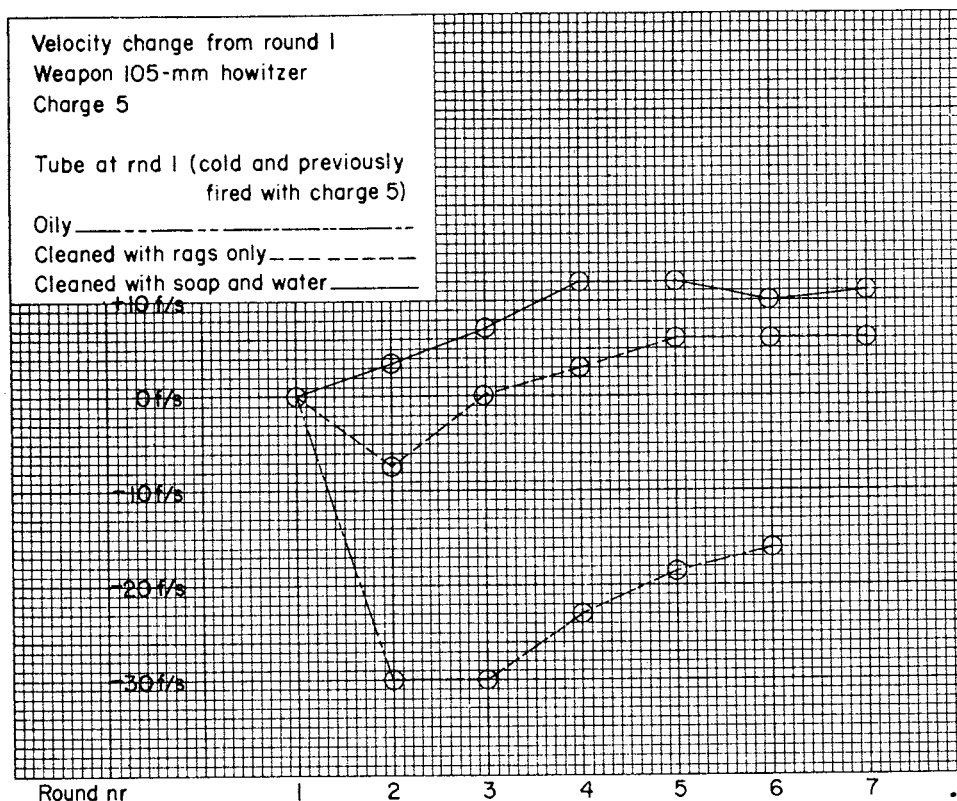


Figure 117. Velocity trends.

and powder residues, it is hard to predict corrections for velocity trends and compensating corrections are uncertain. Moisture on the projectile normally affects only that particular round. As a general rule, firing with a cold dry tube is preferable to firing with a cold oily tube, and projectiles should be dry regardless of tube conditions. Figure 117 illustrates velocity trends measured under the conditions stated. This graph is not to be construed as the basis for determining corrections to firing data. It is merely an example of observed results which most nearly portray the cannon and condition specified after repeated observations.

528. Determination of Muzzle Velocity

The accuracy of artillery fires could be improved if actual muzzle velocities developed by each tube at time of firing were known. Obtaining such data is not feasible at the present time. Therefore, knowledge of past performance of a

weapon-ammunition combination must be relied on for the data needed. In other words, velocity performance is determined when possible and future performance is predicted on this basis. Methods used to determine comparative and absolute velocity performance of a group of weapons are discussed in chapter 21. Aspects of calibration are discussed in detail in exterior ballistics (ch. 28). The velocity level of each weapon must be determined at every opportunity.

529. Charge-To-Charge Propellant Performance

One of the major problems in gunnery is how to extend best the data developed from firing one charge to all other charges. From the viewpoint of developed muzzle velocities only, there is no basis in available data to state that charge-to-charge performance follows a convenient

arithmetical ratio. Since propellants are manufactured to result in standard performance within any given charge, a variation from standard in one charge does not fix a similar or proportional variation in another charge. The velocity level for a charge of a particular lot can be determined only by firing. Once the

velocity level is determined, its relative level, with respect to other charges of that lot similarly determined, remains fairly stable. The velocity level developed at a given time by a certain charge is influenced by the state of the tube conditioning. This is particularly noticeable in the lower charges.

CHAPTER 28

EXTERIOR BALLISTICS

Section I. THE TRAJECTORY IN A VACUUM

530. Introduction

a. Exterior ballistics is the science which deals with the factors affecting the motion of a projectile after it has left the muzzle of a piece; at that instant, the total effect of interior ballistics in terms of developed muzzle velocity and spin have been imparted to the projectile. Were it not for gravity and the atmosphere, the projectile would continue indefinitely at constant velocity along a prolongation of the tube.

b. Gravity causes the projectile to return to the surface of the earth. If the projectile were fired in a vacuum, the path it would follow would be simple to trace. All projectiles, regardless of size, shape, or weight, would follow paths of the same shape and would achieve the same range for a given muzzle velocity and tube elevation. In the atmosphere, however, this path, or trajectory, becomes a complex curve. There are two reasons for this. First, projectiles of different sizes or weights respond differently to identical atmospheric conditions. Second, a standard atmosphere can be defined, but it is seldom experienced. The combinations and permutations of the variables affecting the atmosphere (and, thus, the path of a projectile) are great in number. A given elevation and muzzle velocity can result in a wide variety of trajectories, depending on the combined properties of both the projectile and the atmosphere.

c. The various elements of the trajectory are described in chapter 2. The purpose of this chapter is to picture the trajectory, first, in a vacuum and, second, in the atmosphere. This chapter will include a discussion of the projectile and the atmosphere and the interrelation of the two.

531. Velocity Components

The factors which must be known to construct a firing table for firing in a vacuum are the quadrant angle of departure, the muzzle velocity and the acceleration due to the force of gravity. The initial velocity imparted to a projectile consists of two components—a horizontal velocity and vertical velocity.

532. Horizontal and Vertical Velocity Components

a. The relative magnitudes of horizontal and vertical velocity components vary with the angle of elevation. For example, if the elevation were zero, the initial velocity imparted to the projectile would be horizontal; there would be no vertical component. If the elevation were 1,600 mils, (disregarding the effect of rotation of the earth) the initial velocity would be vertical; there would be no horizontal component.

b. Gravity causes a projectile in flight to fall to the earth. Because of gravity, the height of the projectile at any instant is less than it would be if no such force were acting on it. In a vacuum, the vertical velocity decreases from the initial velocity to 0 on the ascending branch of the trajectory and increases from 0 to the initial velocity on the descending branch. Zero vertical velocity occurs at the trajectory summit. For every vertical velocity value upward on the ascending branch there is an equal vertical velocity value downward equidistant from the summit on the descending branch. Since there is no resistance to the forward motion of the projectile in a vacuum, the horizontal velocity component is a constant. The acceleration due to the force of gravity (32 feet per second/per second) affects only vertical velocity. The trajectory in a vacuum is shown in figure 118.

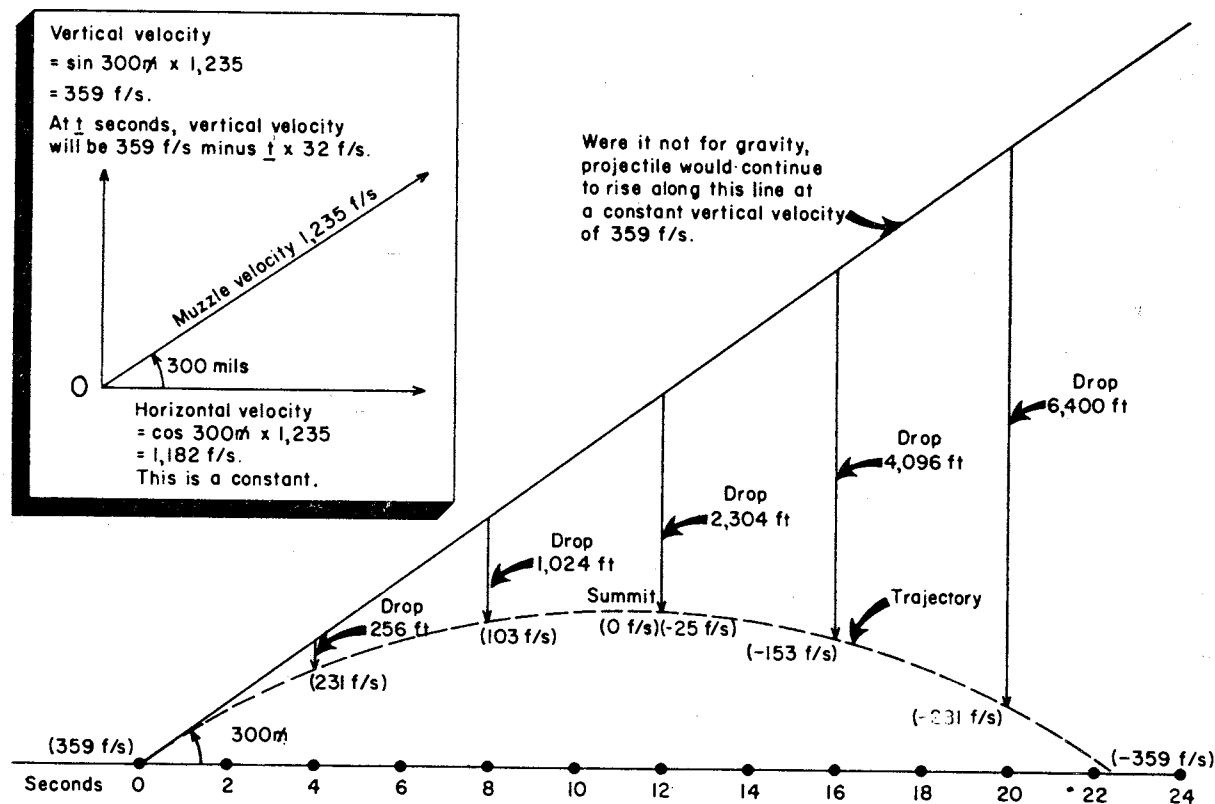


Figure 118. Trajectory in a vacuum.

Section II. THE TRAJECTORY IN THE ATMOSPHERE

533. General

The resistance of the air to a projectile depends on the air movement, density, and temperature. As a point of departure for computing firing tables, an assumed density and temperature structure and condition of no wind are used. The air structure so derived is called "the standard atmosphere."

534. Characteristics of Trajectory in Standard Atmosphere

The most apparent difference between the trajectory in a vacuum and the trajectory in standard atmosphere is the reduction of the range (fig. 119). This is mainly because in the atmosphere the horizontal velocity component is no longer a constant but is continually de-

creased by the retarding effect of the air. The vertical velocity component is likewise affected by air resistance. The trajectory in standard atmosphere has the following characteristic differences from the trajectory in a vacuum:

a. The velocity at the level point is less than the velocity at origin.

b. The mean horizontal velocity of the projectile beyond the summit is less than the mean velocity before the summit; therefore, the projectile travels a shorter horizontal distance. Hence, the descending branch is shorter than the ascending branch. The angle of fall is greater than the angle of elevation. Also, since the mean vertical velocity is less beyond the summit than before it, the time of descent is greater than the time of ascent.

c. The spin (rotational motion) initially imparted to the projectile causes it to respond differently than in a vacuum because of air resistance. A trajectory in standard atmosphere, as opposed to one in a vacuum, will be shorter and lower after any specific time of flight. This is because—

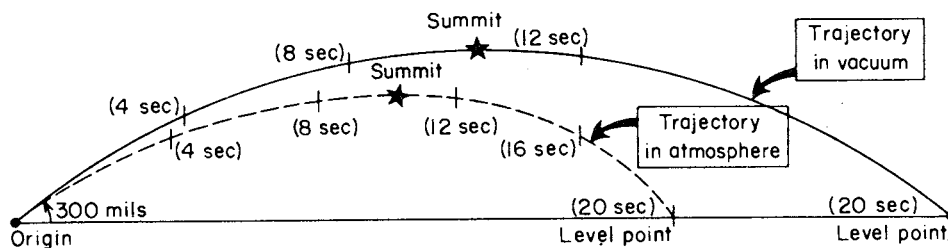
- (1) *Horizontal velocity* is no longer a constant but decreases with each succeeding time interval.

- (2) *Vertical velocity* is affected not only by gravity but also by the additional retardation from the atmosphere.
- (3) The *summit* in a vacuum is midway between the origin and the level point; in the atmosphere, it is nearer the level point.
- (4) The *angle of fall*, in a vacuum, is equal to the angle of elevation; in the atmosphere, it is greater.

A trajectory in standard atmosphere, as opposed to one in a vacuum, will be at a shorter range and of a lower height after any specific time of flight

This is because—

- (1) *Horizontal velocity* is no longer a constant but decreases with each succeeding time interval.
- (2) *Vertical velocity* is affected not only by gravity but also by the additional slowing down from the atmosphere.



Note.

- (1) The *summit* in a vacuum is midway between the origin and the level point; in the atmosphere, it is nearer the level point.
- (2) The *angle of fall*, in a vacuum, is equal to the angle of elevation; in the atmosphere, it is greater.

Figure 119. Trajectory in standard atmosphere.

Section III. RELATION OF AIR RESISTANCE AND PROJECTILE EFFICIENCY TO STANDARD RANGE

535. General

This section pertains only to those factors which establish the standard range and elevation relations.

a. The standard range is the range opposite a given elevation in the firing tables. It is assumed to be measured along the surface of a sphere concentric with the earth and passing through the muzzle of a weapon. For practical purposes, standard range is the horizontal distance from origin to level point.

b. The attained range is the range which is

developed as a result of firing with a certain elevation of the tube. If actual firing conditions duplicate the ballistic properties and meteorological conditions on which the firing table is based, the attained range and standard range will be equal.

c. The corrected range is that range which corresponds to the elevation that must be fired to reach the target.

536. Drag

Air resistance affects the flight of the projectile both in range and direction. The com-

ponent of air resistance in the direction opposite to that of the forward motion of the projectile is called drag. Because of drag, both the horizontal and vertical components of velocity are less at any given time of flight than they would be if drag were zero, as in a vacuum. This decrease in velocity varies directly in magnitude with drag and inversely with the mass of the projectile. This means, in terms of attained range, the greater the drag, the shorter the range; and the heavier the projectile, the longer the range—all other factors being equal. Several factors considered in the computation of drag are—

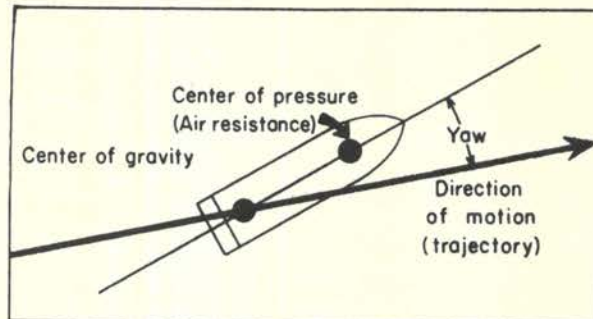
a. *Air Density.* The drag of a given projectile is proportional to the density of the air through which it passes. For example, an increase in air density by a given percentage increases the drag by the same percentage. Since the air density at a particular place, time, and altitude varies widely, the standard trajectories reflected in the firing tables are computed with a fixed relation between density and altitude.

b. *Velocity.* The faster a projectile moves, the more the air resists its motion. Examination of a set of firing tables shows that for a constant elevation, the effect of 1 percent air density (hence 1 percent drag) increases with an increase of charge; that is, muzzle velocity. The drag is approximately proportional to the square of the velocity except in the vicinity of the velocity of sound. There the drag increases more rapidly on account of the increase in pressure behind the sound wave.

c. *Diameter.* Two projectiles of identical shape but different size will not experience the same drag. For example, a large projectile will offer a large area for the air to act upon; hence its drag will be increased by this factor. The drag of projectiles of the same shape is assumed to be proportional to the square of the diameter.

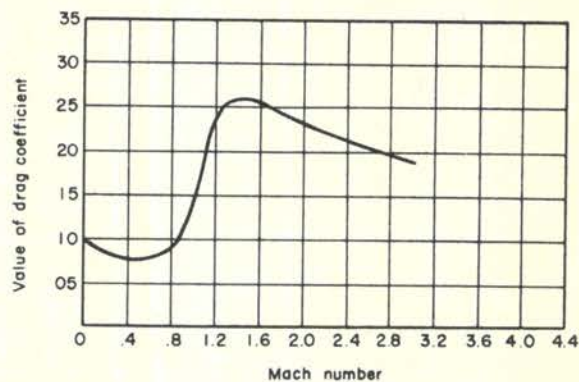
d. *Drag Coefficient.* The drag coefficient combines several ballistic properties of typical projectiles. These properties include yaw (the angle between the direction of motion of the projectile and the axis of the projectile (fig. 120) and the ratio of the velocity of the projectile to the speed of sound (fig. 121)). Drag coefficients, which have been computed for many typical projectile types, greatly simplify the work of

ballisticians. When a projectile varies slightly in shape from one of these typical projectile types, its approximate drag coefficient can be found by computing a form factor and by multiplying the drag coefficient of the typical projectile type by this single form factor.



(Air resistance is least when center of pressure is on the trajectory; that is, zero yaw)

Figure 120. Yaw of projectile in flight.



$$1. \text{ Mach number} = \frac{\text{velocity of projectile}}{\text{speed of sound}}$$

2. The speed of sound is faster in warmer air; hence an increase (decrease) in air temperature decreases (increases) the mach number.
3. A change in the mach number can change the value of the drag coefficient either upward or downward, depending on the mach number at which the change occurs.
4. An increase (decrease) in the value of the drag coefficient decreases (increases) the developed range.

Figure 121. Effect of velocity (Mach number) on drag coefficient of projectile type 1.

537. Ballistic Coefficient

a. The ballistic coefficient of a projectile is a measure of its relative efficiency in overcoming air resistance as compared with the efficiency of the typical projectile to which it is most nearly related. An increase in the ballistic coefficient reduces the effect of drag and consequently increases the range. The reverse is

true for a decrease in ballistic coefficient. The ballistic coefficient can be increased by increasing the ratio of the weight of the projectile to the square of its diameter. It can also be increased by improving the shape of the projectile.

b. Present gunnery techniques recognize the importance of precise muzzle velocity data and

the need for corrections for nonstandard velocities. It is equally important to recognize that errors are introduced in firing projectiles with nonstandard ballistic coefficients. In the past, the effect of nonstandard ballistic coefficients has been treated as a velocity error. However it is not, in fact, a velocity error.

Section IV. FIRING TABLES

538. General

a. Firing tables are based on actual firings of the piece and its ammunition under, or correlated to, a set of conditions defined and accepted as standard. These standards are points of departure used to compensate for variables in the weapon-weather-ammunition combination that are known to exist at a given instant and location. The atmospheric standards accepted in U.S. firing tables reflect the mean annual condition in the North Temperate Zone. Since firing tables are based on assumed standards, they are most accurate for conditions near these standards; large variations from standard or combinations of large variations are not readily corrected for with firing table factors developed to correct the effect of small variations.

b. The principal elements measured in experimental firings include angle of elevation, angle of departure, muzzle velocity, attained range, drift, and concurrent atmospheric conditions.

c. The main purpose of a firing table is to provide the data required to bring effective fire on a target under any set of conditions. To obtain data for firing tables, firings are conducted with the weapon at various quadrant elevations. Computed trajectories, based on the equations of motion, are compared with the data obtained in the firings. The computed trajectories are then adjusted to what actually occurred and the data tabulated. Data for elevations not fired are determined by interpolation. Firing table data defines the performance of a projectile of known properties under conditions of standard muzzle velocity and weather, and a motionless earth.

539. Unit Corrections

a. In firing table similar to FT 155-Q-3, unit corrections are described as *range correc-*

*tion for an increase (decrease) of * * **, followed by the appropriate unit value in meters.

b. Each correction is computed on the assumption that all other conditions are standard. Actually, any given correction will differ slightly from that computed if one or more of the other conditions are nonstandard. The amount of differences depends on the effect of the other nonstandard conditions. The effect of one nonstandard condition on the effect of another nonstandard condition is known as an interaction effect. The error introduced by interaction can be reduced by using an electronic computer.

c. In firing tables similar to FT 155-AI-0, unit corrections are described in separate tables. Those tables are *Correction in Mils for an Increase of * * ** and *Correction in Mils for a Decrease of * * **. The format used in the tables permits computing corrections to time of flight as separate and distinct from corrections to elevation.

d. Effects and corrections, in meters or mils, are not of equal magnitude when computed at the same range. The relationship between effects and corrections at a given range can be expressed as follows:

$$\text{Corrections} = \frac{\text{standard range}}{\text{standard range} + \text{effects}} \times \text{effects}$$

$$\text{Corrected range} = \frac{\text{standard range}}{\text{standard range} + \text{effects}} \times \left\{ \begin{array}{l} \text{standard} \\ \text{range} \end{array} \right.$$

For example, a CI registration is fired by a 155-mm howitzer firing charge 7, elevation 322 (standard elevation for 10,000 meters). The measured range to the center of impact is 9,500 meters. The total effect of all nonstandard conditions is -500 meters. The GFT setting from the CI registration is GFT A: Charge 7, lot ZT, range 9,500, elevation 322. Using the GFT setting, the elevation to achieve range 10,000 meters is 351 (the elevation for 10,530 meters). The total range correction is +530 meters.

540. Extracting Data From Firing Tables

a. The effect of a nonstandard condition is a function of the time the projectile is exposed to that condition. In the 280-mm gun firing tables, the relationship of corrections to time of flight is resolved by presenting the trajectory in terms of both range and height. In the other cannon firing tables, the relationship of corrections to time of flight can be resolved by entering the tables for unit corrections at the chart range plus complementary range.

b. In computing corrections to be fired, slightly more accurate data can be obtained by a second computation at the first apparent corrected range. (This procedure is called successive approximation.) However, the improvement is marginal.

c. The weather that affects a projectile as related to the met message is described by the maximum ordinate the projectile achieves. This maximum ordinate is most nearly defined by the quadrant elevation fired.

Section V. EFFECT OF NONSTANDARD CONDITIONS

541. General

a. Deviations from the standard condition, if not corrected for in computing firing data, will cause the projectile to impact or burst at some point other than the desired point.

b. Corrections for nonstandard conditions are made to improve accuracy. The accuracy of artillery fires depends on the accuracy and completeness of the data available, computational procedures used, and care in laying the pieces. Accuracy should not be confused with precision. Precision is related to tightness of the dispersion pattern without regard to its proximity to a desired point. Accuracy is related to the location of the center of impact with respect to a desired point.

542. Range Effects

a. Vertical jump is the angle formed by the lines of elevation and departure. The shock of firing causes a momentary vertical and rotational movement of the tube prior to the ejection of the projectile. Vertical jump has the effect of a small change in elevation. The effect of vertical jump depends mainly on the eccentricity of the center of gravity of the recoiling parts with respect to the axis of the bore. In modern weapons, vertical jump is usually small. For this reason, vertical jump is not considered separately in the gunnery problem; it is a minor contributing factor to range dispersion.

b. Droop is the algebraic sum of barrel curvature, untrueness of the breech quadrant seats, and untrueness in assembling the tube to the breech. Its magnitude is defined as the difference between the elevation measured at the muzzle and the elevation measured on the breech quadrant seats. Firing tables are constructed based on measurements at the muzzle. For example, if droop for a certain weapon is—3 mils and an elevation of 360 is set in the normal manner, the tube elevation is only 357 mils; if it is desired to fire a true 360-mil elevation, a setting of 363 would be necessary. At present, droop is treated separately only for the 280-mm gun. In other weapons it is absorbed into the computed velocity error, although in reality it is an elevation error.

c. Muzzle velocity is the speed of the projectile at the time it is projected from the muzzle; the greater the velocity of a given projectile, the greater the attained range. Velocity error often becomes a catchall for many nonvelocity elements. When this occurs, accuracy is adversely affected in subsequent applications of the velocity error.

d. Weight of projectiles affects muzzle velocity. Two opposing factors affect the flight of a projectile of nonstandard weight. A heavier projectile is more efficient in overcoming air resistance; however, because it is more difficult to push through the tube, its muzzle velocity is

lower. An increase in projectile efficiency increases range, but a decrease in muzzle velocity decreases range. In firing tables, corrections for these two opposing factors are combined into a single correction. The change in muzzle velocity predominates at shorter times of flight; the change in projectile efficiency predominates at longer times of flight. Hence, for a heavier than standard projectile, the correction is plus at the shorter times of flight and minus at the longer times of flight. The reverse is true for a lighter than standard projectile.

e. Range wind is that component of the ballistic wind blowing parallel to the direction of fire and in the plane of fire. The plane of fire is a vertical plane that contains the line of elevation. Range wind changes the relationship between the velocity of the projectile and the velocity of the air near the projectile. If the air is moving with the projectile (tailwind), it offers less resistance to the projectile and a longer range results; headwind has the opposite effect.

f. The effects of nonstandard air temperature may appear inconsistent and puzzling at first. For example, an increase in air temperature increases the velocity of sound which in turn decreases the Mach number (previously defined as projectile velocity divided by the velocity of sound in air). Drag is related to the Mach number. The relationship changes abruptly in the vicinity of Mach 1 when projectile velocity equals the velocity of sound. See figure 121 for a chart of this changing relationship. Note that a decrease in the Mach number (increases in temperature) will at times lead to an increase in drag and at other times lead to a decrease in drag, depending on the terminal velocity at the range being considered.

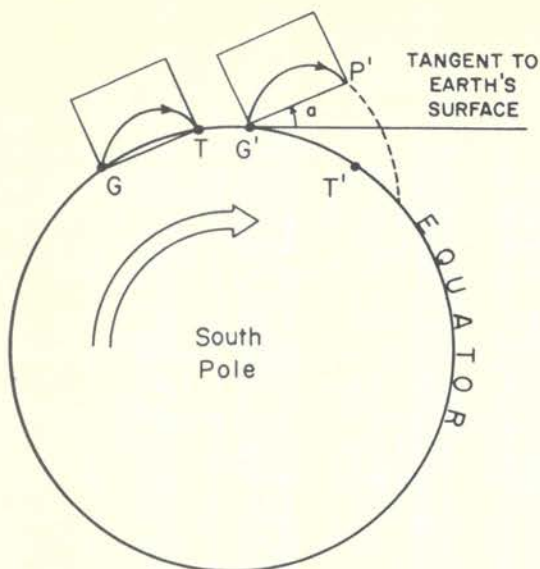
g. Air density effects have been previously discussed as directly related to the drag coefficient, with the more dense air offering greater resistance and vice versa (par. 536).

h. Although the earth rotates at a constant rate, the correction for rotation varies with a number of factors and therefore rotation is more readily corrected for as a nonstandard condition. Factors influencing the effect of rotation of the earth upon the travel of a pro-

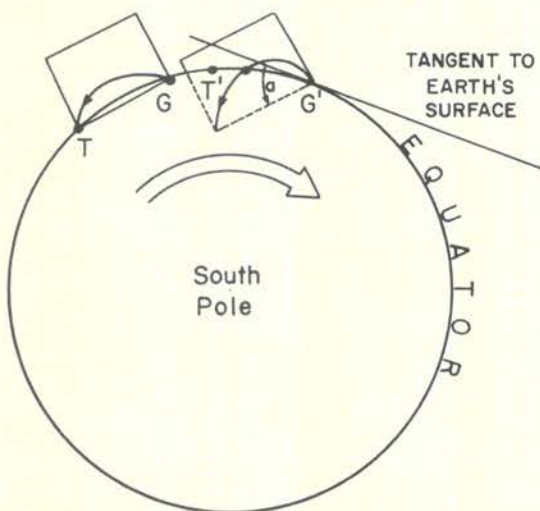
jectile are direction of fire, angle or departure, velocity of projectile, range to the target, and the latitude of the gun. Corrections for these factors are combined in convenient tabular form in firing tables. The firing tables are all that are needed to compensate for rotation in the gunnery problem. However, some background theory of rotational effects may assist in an understanding of ballistics.

(1) Owing to rotation of the earth, a point on the Equator has an eastward linear velocity of approximately 1,500 feet per second. This linear velocity decreases to zero at either pole. Consider a gun on the Equator firing due east at a target (1, fig. 122). During the time of flight of the projectile, the gun and target will travel from G to G' and T to T', respectively, along the circumference of the earth. The projectile, however, travels in a vertical plane, the base of which is parallel to the original plane of departure established at the time of firing; that is, it is pivotal to the circumference of the earth at the gun but not at the target. At the end of a given time of flight, the projectile will be at P' when the target is at T'. Hence, the projectile will continue along an extended trajectory and land farther east or, in this instance, beyond the target. 2, figure 122 depicts firing westward. The normal trajectory of the projectile is interrupted. Again, the projectile falls to the east of the target but in this instance east is short. The effect in each example is as if the quadrant elevation fired had been in error by the amount of angle α , which is the angle formed by the base line G'P' and a tangent to the earth at G'. Firing eastward, α is plus (range over); firing westward, α is minus (range short).

(2) If a projectile were fired straight up (elevation 1,600 mils) as shown in figure 123, both the projectile and gun will have the same eastward velocity imparted to them owing to rotation



(1) Rotational effects on range firing eastward



(2) Rotational effects on range firing westward

Figure 122. Rotational effects.

of the earth; hence, during the time of flight, both will travel the same arc distance. The projectile will travel the mean arc PP' , which is on a circle of greater radius than that of the arc GG' which is traveled by the gun. The direction of gravity is always towards the center of the earth. Since the projectile is moving eastward, owing to rotation of the earth, the force of

gravity acts to pull it back to the west; that is, opposite to the direction of rotation. The projectile appears to lag behind (west of) the gun. This gravitational effect is at a maximum at an elevation of 90° and is always opposite to the effect described in (1) above. It eventually predominates

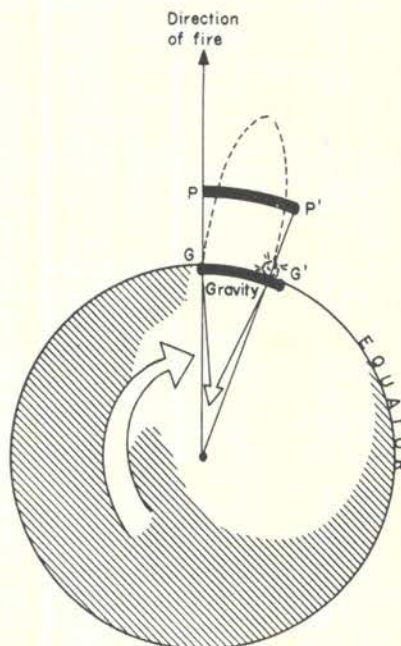


Figure 123. Projectile lag due to rotation of the earth.

over the preceding effect at an elevation of 60° . The former effect is at a maximum at 30° elevation. An examination of rotation correction tables, firing due east, for example, shows a minus range correction at the lowest range, gradually increasing, then decreasing, and finally changing in sign to a plus. In firing due west, all signs are reversed.

- (3) A third consideration is the curvature effect. Curvature effect exists because of the use of a map range, for which the surface of the earth is assumed to be flat, but the actual range is measured on a sphere. The GT range is computed for a plane tangent to the surface of the earth at the gun. When the projectile reaches this range, it is still above the curved surface of the

earth and will continue to drop, resulting in a slightly longer true range than desired. This effect is of little significance except at very long ranges. It is disregarded when firing tables are used, since firing table ranges include curvature effect.

- (4) A final rotational effect is described as the latitudinal effect. When the gun and target are at different latitudes, the eastward rotational velocity imparted to the projectile and the target are different. For example, if the gun is nearer the Equator (1, fig. 124), the projectile will travel faster and therefore farther to the east than the target (the effect left or right depends on the hemisphere). When the gun and target are at the same latitude (2, fig. 124), the projectile will also be deflected away from the target. This is because the projectile tends to travel in the plane of the great circle containing the gun and target at the time of firing. Owing to rotation of the earth, this great circle plane is continuously changing with respect to its original position. As viewed from above, it would appear that the great circle containing the gun and target is turning with respect to the great circle followed by the projectile. An additional latitudinal effect is pictured in 3, figure 124. When the latitude is other than the Equator, the projectile is pulled out of its original vertical plane by the force of gravity which operates from the center of the earth and not on a perpendicular to the axis of the earth.

i. The ballistic coefficient of a projectile relates its efficiency in overcoming air resistance to that of an assumed standard projectile. For ease in computations, all projectile types are classified into certain standard groups. Each projectile, however, has its own efficiency level. Each projectile lot has its own average efficiency level; that is, ballistic coefficient. In order to establish firing tables, it is necessary to select and fire one specific projectile lot. Based

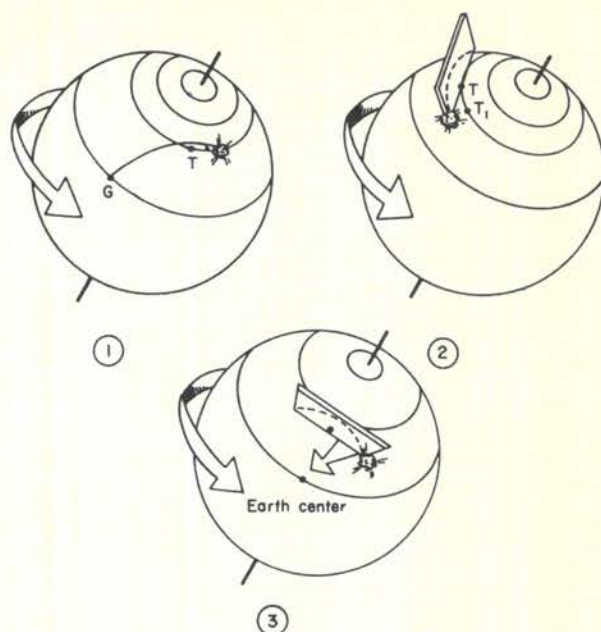


Figure 124. Latitudinal effect.

on the performance of this lot, standard ranges are determined. The ballistic coefficient of this particular projectile lot becomes the firing table standard. However, other projectile lots of the same type will not have the same ballistic coefficient as the one reflected in the firing tables. If one of the other lots is more efficient, that is, has a higher ballistic coefficient than the firing table standard, it will develop more range when fired. The reverse is true for a less efficient projectile lot. In present gunnery procedures, variations in propellant performance are considered an element of muzzle velocity; however, variations in ballistic coefficient are also considered an element of muzzle velocity, which is not correct. When the variation in ballistic coefficient is treated as a muzzle velocity element it is difficult to produce accurate firing data throughout the entire capability of the gun because the meters per foot per second factor is adapted only to muzzle velocity elements. A change in the ballistic coefficient would require recomputation of the entire firing table; hence, a more convenient means of expressing a change in the ballistic coefficient must be derived if it is to be separated from muzzle velocity in a usable gunnery procedure. The formula for re-

tardation (retardation = $\frac{\text{drag coefficient} \times \text{velocity}^2 \times \text{air density}}{\text{ballistic coefficient}}$) shows

that if the ballistic coefficient is increased by a certain percentage the effect on the retardation is the same as the effect of a decrease in air density of the same percentage. Thus the ballistic coefficient change (BCC) can be expressed and treated as a percentage change in ballistic air density. For example, the ballistic coefficient change for a projectile that is only 97 percent as efficient as the standard projectile is -3 percent. In solving a met message, the ballistic air density, extracted from the proper line of the message, is increased by +3 percent.

543. Deflection Effects

a. Lateral jump is caused by a slight lateral and rotational movement of the tube at the instant of firing. It has the effect of a small error in deflection. The effect is ignored since it is small and varies from round to round.

b. Drift is defined as the departure of the projectile from standard direction because of the combined action of air resistance, projectile spin, and gravity. In order to fully understand the forces that cause drift, it is necessary to understand the angle of yaw, which is that angle between the direction of motion of the projectile and the axis of the projectile. The direction of this angle is constantly changing in a spinning projectile—right, down, left, and up. This initial yaw is at a maximum near the muzzle and gradually subsides as the projectile stabilizes. The atmosphere offers greater resistance to a yawing projectile; therefore, it is fundamental in the design of projectiles that yaw be kept to a minimum and be quickly damped out in flight. At the summit, where

the descending branch of the trajectory begins, summital yaw is introduced and the effect on the projectile is to keep the nose pointed slightly toward the direction of the spin. Therefore, since artillery shells have a clockwise spin, they drift to the right in the descending branch of the trajectory. The magnitude of drift (expressed as lateral distance on the ground) depends on the time of flight and rotational speed of the projectile and the curvature of the trajectory.

c. The lateral wind is that component of the ballistic wind blowing across the direction of fire. Lateral wind tends to carry the projectile with it and causes a deviation from the direction of fire. However, the lateral deviation of the projectile is not as great as the movement of the air causing it. Wind component tables simplify the reduction of a ballistic wind into its two components with respect to the direction of fire.

d. The effects on deflection from the rotation of the earth are described in paragraph 542h (4) and figure 122.

544. Time of Flight

a. Those nonstandard conditions which affect range also affect time of flight. Also, the fuze settings for current time fuzes, although approximating time of flight, are not interchangeable with time of flight.

b. In some firing tables such as FT 155-AI-0, corrections to fuse setting are computed separately from corrections to elevation. In firing tables which do not have corrections to fuze setting tables, fuze setting is treated as a function of elevation plus complementary angle of site.

Section VI. SUMMARY

545. General

a. Firing tables are based on an accepted standard atmosphere, a motionless earth, and specific ballistic properties of the ammunition. These tables are a point of departure for computing corrections to standard firing data. The

computational procedures used in the field must be compatible with the presentation of data in the firing tables.

b. The main purpose of a firing table is to provide the data required to bring effective fire on a target under any set of conditions. The

most accurate firing table would be a huge compilation of data for every weapon-target relationship and every combination of conditions of the weapon, weather, and ammunition. The simplest firing table would be a straight range-elevation relationship. Firing tables are a compromise between simplicity and accuracy.

c. More accurate solutions to the ballistic phase of the gunnery problem are being sought in the development of high-speed, automatic, electronic digital computers.

546. Determination of Nonstandard Conditions

Firing tables define standard conditions of the weapon-weather-ammunition combination. In computing corrected data, the unit in the field depends on measurements made at the battery and the data in the met message. Also, the unit depends on past experience of the weapon-ammunition combination as expressed in the old velocity error. The data from these sources make up the unit's knowledge of existing nonstandard conditions.

CHAPTER 29

DISPERSION AND PROBABILITY

Section I. USE OF DISPERSION DIAGRAM AND PROBABILITY TABLE

547. General

a. Dispersion and probable error are discussed in paragraphs 30 through 40.

b. This chapter will discuss the use of dispersion diagrams and scales, probability, and assurance.

548. Application of Probable Errors

a. Normal distribution is expressed in terms of probable errors (PE's) because the distribution of bursts about the mean is the same regardless of the magnitude of the probable error. Firing tables list PE's for range, deflection, height of burst, and time of burst at each listed range. It is possible to express a given distance in terms of PE's and solve problems by using the dispersion scale or probability tables.

b. To compute the probability of a round landing within an error of a certain magnitude,

reduce the specified error to equivalent PE's, add the percentages associated with this number of PE's in one direction along the dispersion scale, and multiply the sum by 2. For example, a 155-mm howitzer has fired a number of rounds with charge 7, and the center-of-impact has been determined to be at 11,500 meters. What is the probability that the next round fired will fall within 80 meters of the center-of-impact?

Solution:

Range PE at 11,500 meters (charge 7) = 40 meters
 Equivalent of 80 meters in PE's (80/40) = 2
 Percent of rounds falling within 2 PE = 2(25% + 16%) (fig. 10) = 82 percent

549. Probability Table (Table VI)

The computation of probability is simplified by the use of probability tables.

Table VI. Normal Probability Tables, Areas of the Normal Probability Curve
 (t is expressed in probable errors)

t	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0----	0.0000	0.0027	0.0054	0.0081	0.0108	0.0135	0.0162	0.0189	0.0216	0.0243
0.1----	.0269	.0296	.0323	.0350	.0377	.0404	.0431	.0457	.0484	.0511
0.2----	.0538	.0565	.0591	.0618	.0645	.0672	.0699	.0725	.0752	.0778
0.3----	.0804	.0830	.0856	.0882	.0908	.0934	.0960	.0986	.1012	.1038
0.4----	.1064	.1089	.1115	.1140	.1166	.1191	.1217	.1242	.1268	.1293
0.5----	.1319	.1344	.1370	.1395	.1421	.1446	.1472	.1497	.1522	.1547
0.6----	.1572	.1597	.1622	.1647	.1671	.1695	.1719	.1743	.1767	.1791
0.7----	.1815	.1839	.1863	.1887	.1911	.1935	.1959	.1983	.2007	.2031
0.8----	.2054	.2077	.2100	.2123	.2146	.2169	.2192	.2214	.2236	.2258
0.9----	.2280	.2302	.2324	.2346	.2368	.2390	.2412	.2434	.2456	.2478
1.0----	.2500	.2521	.2542	.2563	.2584	.2605	.2626	.2647	.2668	.2689
1.1----	.2709	.2730	.2750	.2770	.2790	.2810	.2830	.2850	.2869	.2889
1.2----	.2908	.2927	.2946	.2965	.2984	.3003	.3022	.3041	.3060	.3078
1.3----	.3097	.3115	.3133	.3151	.3169	.3187	.3205	.3223	.3240	.3258
1.4----	.3275	.3292	.3309	.3326	.3343	.3360	.3377	.3393	.3410	.3426
1.5----	.3442	.3458	.3474	.3490	.3506	.3521	.3537	.3552	.3567	.3582
1.6----	.3597	.3612	.3627	.3642	.3657	.3671	.3686	.3700	.3714	.3728
1.7----	.3742	.3756	.3770	.3784	.3798	.3811	.3825	.3838	.3851	.3864
1.8----	.3877	.3890	.3903	.3915	.3928	.3940	.3952	.3964	.3976	.3988
1.9----	.4000	.4012	.4024	.4035	.4047	.4058	.4069	.4080	.4091	.4102
2.0----	.4113	.4124	.4135	.4146	.4156	.4167	.4177	.4187	.4197	.4207
2.1----	.4217	.4227	.4237	.4246	.4256	.4265	.4274	.4283	.4292	.4301

Table VI. Normal Probability Tables, Areas of the Normal Probability Curve—Continued

(t is expressed in probable errors)

t	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.2	.4310	.4319	.4328	.4336	.4345	.4353	.4361	.4369	.4377	.4385
2.3	.4393	.4401	.4409	.4417	.4425	.4433	.4441	.4448	.4456	.4463
2.4	.4470	.4477	.4484	.4491	.4498	.4505	.4512	.4519	.4526	.4533
2.5	.4540	.4547	.4553	.4560	.4566	.4572	.4578	.4584	.4590	.4596
2.6	.4602	.4608	.4614	.4620	.4625	.4630	.4636	.4641	.4646	.4651
2.7	.4657	.4662	.4667	.4672	.4677	.4682	.4687	.4692	.4697	.4701
2.8	.4705	.4710	.4714	.4718	.4722	.4727	.4731	.4735	.4739	.4743
2.9	.4748	.4752	.4756	.4760	.4764	.4768	.4772	.4776	.4780	.4783
3.0	.4787	.4790	.4793	.4796	.4800	.4803	.4806	.4809	.4812	.4815
3.1	.4818	.4821	.4824	.4827	.4830	.4833	.4836	.4839	.4842	.4845
3.2	.4848	.4851	.4853	.4855	.4857	.4859	.4862	.4864	.4866	.4868
3.3	.4870	.4873	.4875	.4877	.4879	.4881	.4883	.4885	.4886	.4888
3.4	.4890	.4892	.4893	.4895	.4897	.4899	.4901	.4902	.4904	.4906
3.5	.4908	.4909	.4911	.4913	.4915	.4916	.4917	.4919	.4921	.4922
3.6	.4923	.4924	.4926	.4927	.4928	.4929	.4931	.4933	.4934	.4935
3.7	.4936	.4938	.4939	.4940	.4941	.4942	.4944	.4945	.4946	.4947
3.8	.4948	.4949	.4950	.4951	.4952	.4953	.4953	.4954	.4955	.4956
3.9	.4957	.4958	.4959	.4960	.4960	.4961	.4962	.4963	.4964	.4965
4.0	.4965	.4966	.4967	.4967	.4968	.4969	.4969	.4970	.4971	.4972
4.1	.4972	.4973	.4973	.4974	.4974	.4975	.4975	.4976	.4976	.4977
4.2	.4978	.4978	.4979	.4979	.4980	.4980	.4980	.4981	.4981	.4981
4.3	.4982	.4982	.4982	.4983	.4983	.4983	.4983	.4984	.4984	.4985
4.4	.4985	.4985	.4986	.4986	.4986	.4987	.4987	.4987	.4988	.4988
4.5	.4988	.4989	.4989	.4989	.4989	.4990	.4990	.4990	.4990	.4991
4.6	.4991	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4992	.4992
4.7	.4993	.4993	.4993	.4993	.4993	.4993	.4994	.4994	.4994	.4994
4.8	.4994	.4994	.4994	.4995	.4995	.4995	.4995	.4995	.4995	.4995
4.9	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.4996	.4996
5.0	.4996	.4996	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997
5.1	.4997	.4997	.4997	.4997	.4998	.4998	.4998	.4998	.4998	.4998
5.2	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998	.4998
5.3	.4998	.4998	.4998	.4998	.4998	.4998	.4999	.4999	.4999	.4999
5.4	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.5	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.6	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.7	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999	.4999
5.8	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000
5.9	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000	.5000

a. The entire area under the normal probability curve is unity or 100 percent. The ratio of any particular portion of the area to the total area represents the probability that the burst in question will occur within the interval over which the particular area stands. For example, consider that portion of the total area which stands over the interval from the mean to a distance of 1 probable error on one side of the mean. This is 25 percent of the total area under the curve. Numbers in the body of the table are areas under the normal probability

curve. The arguments are distances, expressed in probable errors. In the first vertical column are distances, expressed in probable errors to the nearest tenth; horizontally across the top of the table is the breakdown in hundredths of probable errors. Entry into the table is similar to entry into a table of logarithms. The total area under the probability curve is taken as one. Note that the maximum area defined in the body of the table is 0.5000, or 50 percent, or one-half. Therefore, the numbers in the body of the table actually give the probability that

the event in question will occur within various probable errors from the mean and on one side only of the mean. Interpolation in the tables is an unnecessary refinement. A complete set of probability tables for one side of the mean is shown below:

b. The example in paragraph 546b can be solved by the use of the probability tables as follows:

Equivalent PE's.....	2.0
Value from table VI.....	0.4113
Probability (0.4113×2).....	82.26 percent

The answer differs slightly from that obtained by using the dispersion scale because probability tables are to an accuracy of four decimal places and are entered with probable error expressed to the hundredth, whereas the dispersion scale is to an accuracy of only two decimal places and is entered with whole probable errors. Probability tables provide the more accurate answer.

c. In some problems, the probability is required for only one side of the mean in which case the multiplication by 2 is omitted. For example, to determine the probability that a burst will be closer to the ground than 100 meters when the mean height of burst is 350 meters above the ground and the height of burst probable error (PE_h) is 75 meters, the following procedures are used:

Specified error (meters) = $350 - 100 =$
(250 meters below the mean is 100
meters above the ground)

Error in $PE_h = 250/75 = 3.33$

From probability table VI, 3.33 corresponds to 0.4877 which is the probability that the burst will be between the mean and 100 meters above the ground. Since the total probability for a burst being below the mean is 0.5000, then the probability of a burst being less than 100 meters above the ground, that is, more than 250 meters below the mean, is: $0.5000 - 0.4877 =$
1.23 percent.

By extension, the probability that the burst will occur at either less than 100 meters above the ground (250 below the mean) or more than 600 meters above the ground (250 above the

mean) is $1.23\% + 1.23\% = 2.46\%$. Any combination of limiting height above the ground can be similarly solved. The maximum and minimum limits specified need not reduce to the same error from the mean as in the foregoing example. Each is solved independently and the probabilities are added.

d. It is emphasized that the probability table gives the probability of not exceeding a certain error or, by subtraction, the probability of making an error equal to or less than a specified error. The probability tables cannot give the probability of making a particular error. Though there is little application for the computation in artillery, a computation could be made to give the probability of making an error falling within a prescribed range. By combining some of the computations already discussed, it would be relatively simple to determine the probability of making an error greater than 100 meters and less than 110 meters.

e. The major reason for the difference in figures derived from the dispersion scale and those from the probability table is that linear interpolation is used with the dispersion scale when the conversion of a distance to PE's results in a fractional value. The assumption that the distribution of bursts is uniform within the limits of 1 probable error is false.

550. Most Probable Position of Center-of-Impact

Thus far, only the probability of an outcome of a future event has been considered. This is not always the problem. For example, the observer's sensings in the fire for effect phase of a precision registration are the outcome of the rounds fired, but they do not in themselves define the relative locations of center-of-impact and target which yielded these sensings. The problem is to find the most probable relative locations.

a. There are simple methods of determining the most probable location of the target with respect to the center-of-impact. These methods are based on, first, the fact that positive range sensings used are of two outcomes only—either over or short—and, second, the assumption that the small number of rounds observed follows normal distribution exactly.

b. For example, if five shorts and one over are obtained, then five-sixths, or 33.33 percent, of the rounds fell short of the target; by using the dispersion scale, the target must be 1.52 probable errors beyond the center-of-impact ($1 \text{ PE} + \frac{8.33}{16} \text{ PE}$, or 1.52 PE, beyond the center-of-impact). By definition, 50 percent of the rounds fell short of the center-of-impact; therefore, 33.33 (83.33—50.00) percent of the rounds fell between the center-of-impact and the target. In the probability tables, 0.3333 represents 1.43 probable errors, to the nearest hundredth, which is a more accurate estimate

of the distance of the target from the center-of-impact. Use of the preponderance formula described in chapter 18 indicates the target to be 1.33 probable errors beyond the center-of-impact

$$\frac{(5-1)}{2 \times 6} \text{ fork} = \frac{1}{3} \text{ fork} = 1.33 \text{ PE}.$$

Probability tables provide the most accurate answer; however, the preponderance formula is used because of its simplicity and because the small number of rounds considered (6) does not warrant striving for the extra theoretical precision of the probability table.

Section II. SINGLE SHOT HIT PROBABILITY AND ASSURANCE

551. General

Single shot hit probability (SSHP) is the probability of hitting a target or area of finite dimensions with any one round.

a. The probability of a round hitting in any one of the areas bounded by 1 range probable error (PE_r) and 1 deflection probable error (PE_d) is the product of the probability of not exceeding that range error and the probability of not exceeding that deflection error. This basic principle is applied in computing the single shot hit probability. To use the probability tables, the specified error must be reduced to equivalent probable errors.

b. Computation of SSHP is based on the assumption that the center-of-impact is at the exact center of the target or area. This means, for example, that if the target is 40 meters deep, the limit of error is 20 meters (fig. 125). The same principle is true for deflection. Therefore, in order to reduce target dimensions to equivalent probable errors, it is first necessary to determine the limit of error for range (i.e., one-half that target dimension parallel to the GT line) and for deflection (i.e., one-half that target dimension perpendicular to the GT line). Then, the limits of error are divided by the respective firing table probable errors for the weapon, charge, and range being used. The quotient (t) is the limit of the error expressed in probable errors and is the argument for entering the probability tables to determine the

range probability and the deflection probability. The product of these two probabilities gives the probability of hitting a specific quarter of the four quarters of the target as shown by the shaded area in figure 125. Since a hit in any one of the four quarters constitutes success, the probability of getting a hit in any quarter must be multiplied by 4.

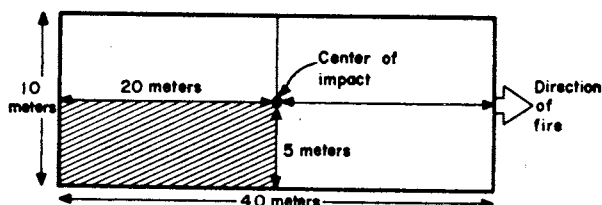


Figure 125. Single shot hit probability.

c. For example, the target is a bridge 10 meters by 40 meters with the long axis parallel to the direction of fire. Range to target is 9870 meters. By precision fire techniques, adjust the center-of-impact on the center of the target. After the center-of-impact is correctly located at the center of the target, computation of SSHP is as follows:

Given: 8-inch howitzer
charge 7
range 9870 meters

From firing table determine PE_r and PE_d . Enter Table G with range rounded to the nearest 100 meters (9900). $\text{PE}_r = 18$ meters;

$PE_d = 3$ meters.

$$\text{Range } t = \frac{1/2(40)}{18} = \frac{20}{18} = 1.11$$

$$\text{Deflection } t = \frac{1/2(10)}{3} = \frac{5}{3} = 1.66$$

From probability tables: $t(1.11) = 0.2730$;
 $t(1.66) = 0.3686$

SSHP = $4(0.2730)(0.3686) = 0.4025 = 40.25$ percent.

552. Single Shot Hit Probability for Bias Targets

a. A target is said to be biased when its specified dimensions are not parallel or at right angles to the direction of fire. The only change in procedure required is that the specified dimensions of the target must first be converted to an effective depth and width which fits the dispersion pattern with respect to the GT line. Once the effective depth and width are known, the computation of SSHP proceeds as in paragraph 551. Figure 126 illustrates a bias target.

b. The following tabulation can be used to approximate these effective dimensions. Greater accuracy is not warranted in view of the ap-

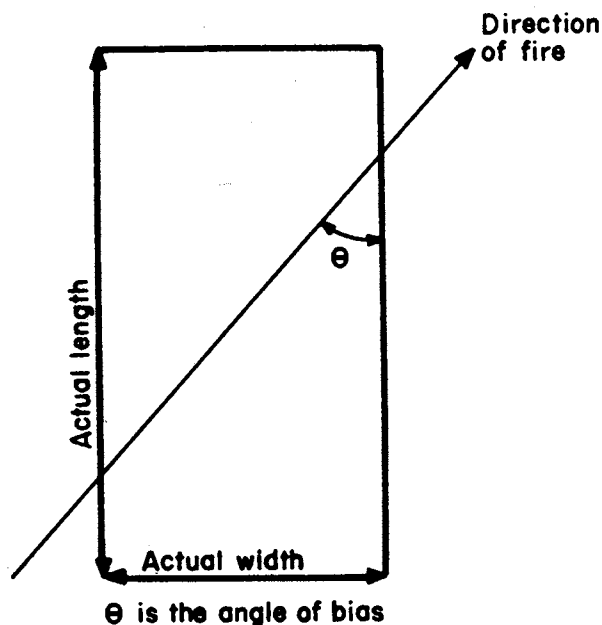


Figure 126. Bias target.

proximate dimensions of the target itself and the approximation of the angle of bias. The angle of bias is the smallest angle measured between the long axis of the target and the direction of fire.

Angle of bias between—	Effective depth	Effective width
0–400 mils	Actual length	Actual width
401–650 mils	$2 \times$ actual width	$0.5 \times$ actual length
651–950 mils	$1.41 \times$ actual width	$0.71 \times$ actual length
951–1,200 mils	$1.15 \times$ actual width	$0.87 \times$ actual length
1,201–1,600 mils	Actual width	Actual length

c. For example, the target is a bridge 8 meters by 40 meters with the long axis at an 800 mil angle to the direction of fire. The range is 11,040 meters. By assuming that the center-of-impact has been adjusted to the center of the target, computation of the SSHP for an 8-inch howitzer firing charge 7 is as follows: Effective depth = 1.41 (from *b* above) $\times 8$ meters = 11.28 (use 11).

$$\text{Range } t = \frac{1/2(11)}{19} = \frac{11}{38} = 0.29$$

Effective width = 0.71 (from *b* above) $\times 40$ meters = 28.40 (use 28).

$$\text{Deflection } t = \frac{1/2(28)}{3} = 4.67$$

From probability tables: $t(0.29) = 0.0778$; $t(4.67) = 0.4922$.

SSHP = $4(0.0778)(0.4992) = 0.1553$ or 15.53 percent.

553. Conversion of a Circular Target to an Equivalent Rectangle

a. Many targets are described as circular. In order to compute the SSHP for a circular target, it is necessary to convert the target to a square of the same area. This conversion is necessary because the dispersion pattern of cannons is elliptical and can be reasonably defined by a rectangle.

b. To convert from a circular shape to a rectangular (square) shape, the radius of the circle is multiplied by 1.7725 (1.7725 is the square root of π). The product is the length of a side of a square which has an area equal to the area of the original circle.

554. Assurance and Assurance Graphs

The term "assurance" is another way of saying probability. Single shot hit probability is a specific instance of assurance wherein only one round is considered. Assurance is a broader term associated with the probability of hitting a target with any given number of rounds, assuming a constant single shot hit probability.

a. The assurance formulas for at least one hit, two hits, three hits, etc., may be graphed as shown in figures 127, 128, and 129. The only computation necessary is the single shot hit probability. Once that is known, the graph pro-

vides a rapid determination of either the assurance obtainable from firing a specified number of rounds (N) or the number of rounds required for a desired assurance.

b. The number of rounds is indicated along the bottom of the graph, the SSHP is indicated up the side of the graph, and the assurance is indicated by the curves drawn within the graph. To use the assurance graph, find the intersection of the two known elements and then read the desired element opposite this intersection. Interpolation between numbered graduations is permissible.

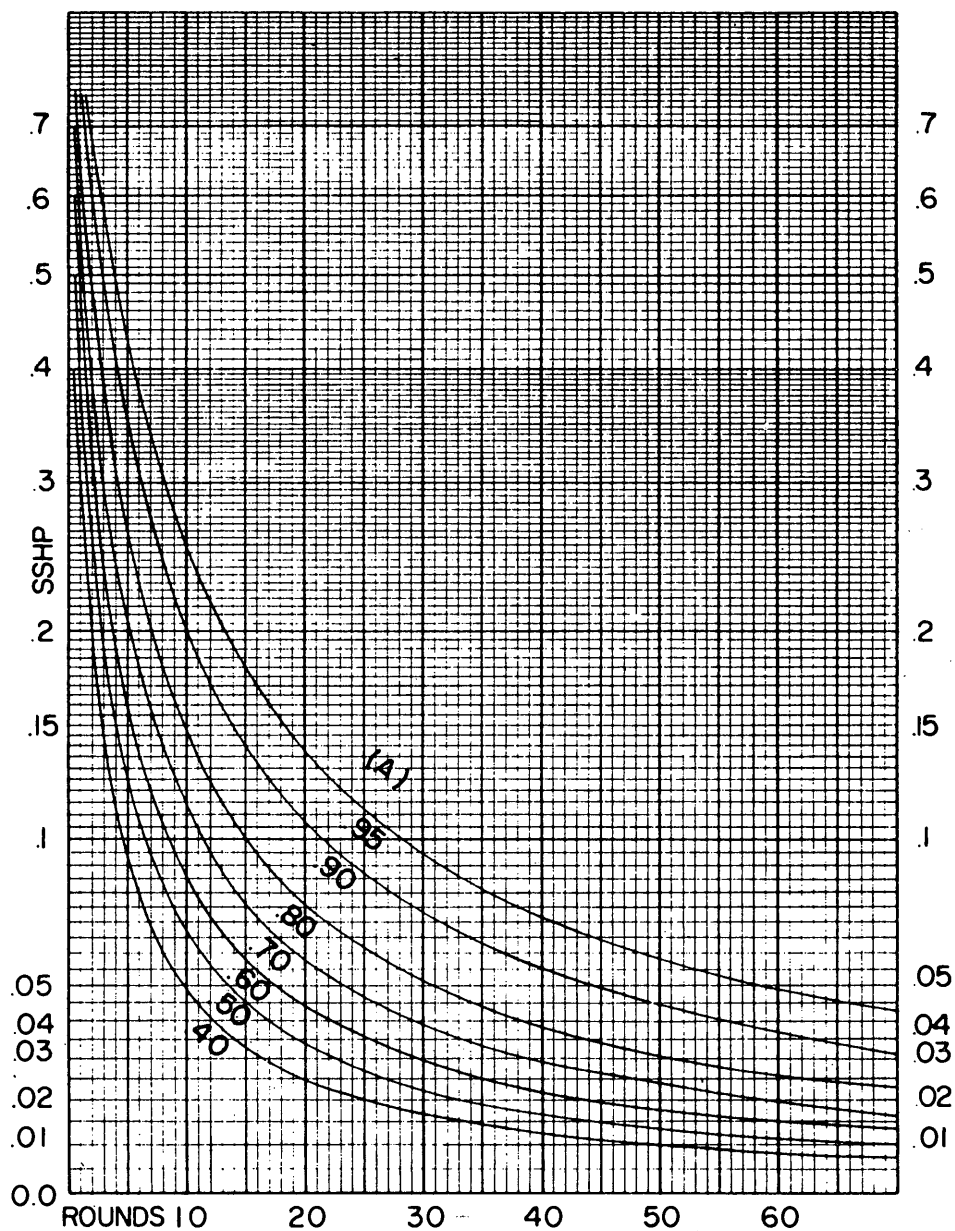


Figure 127. Assurance of at least one hit for "N" rounds when single shot hit probability is known.

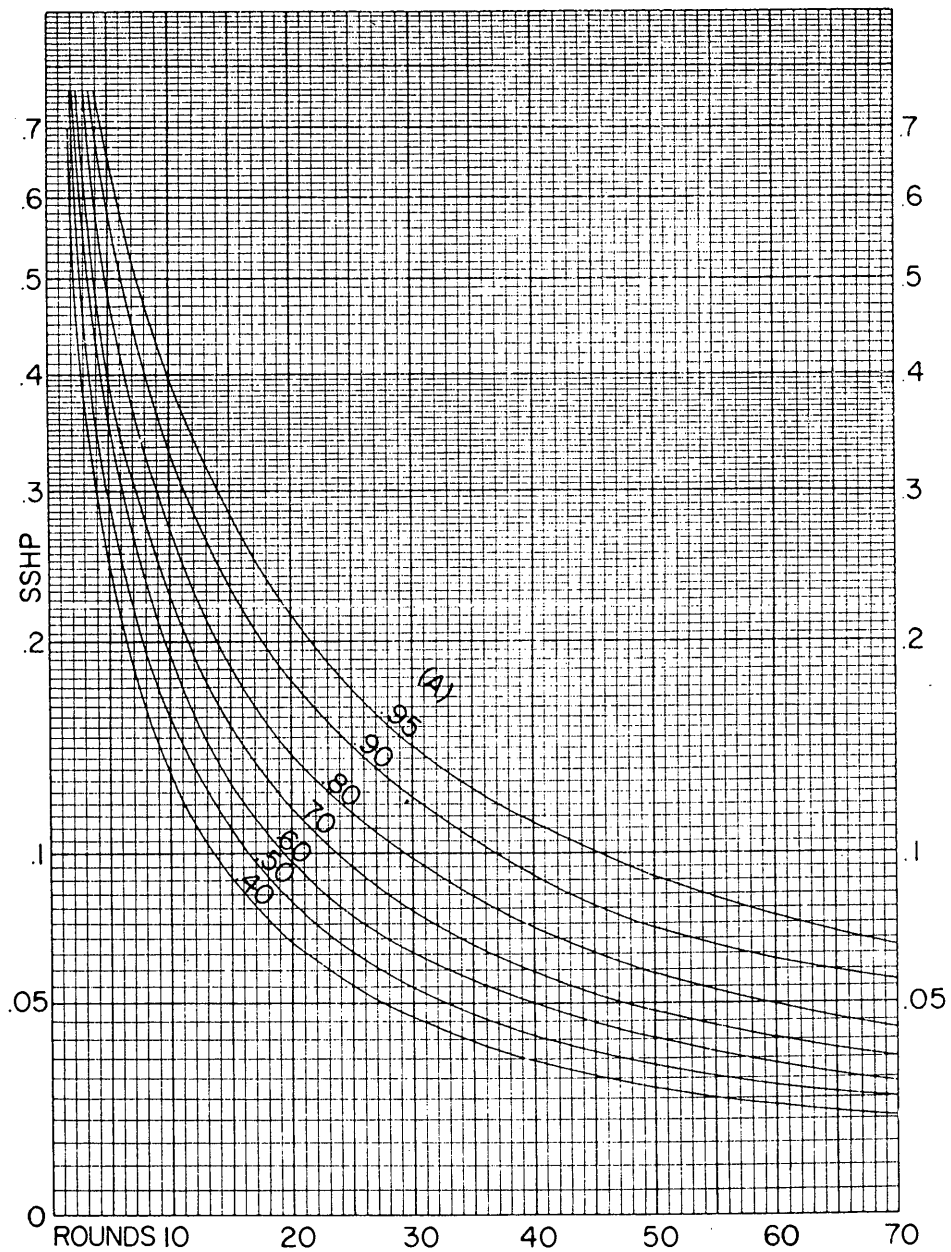


Figure 128. Assurance of at least two hits for "N" rounds when single shot hit probability is known.

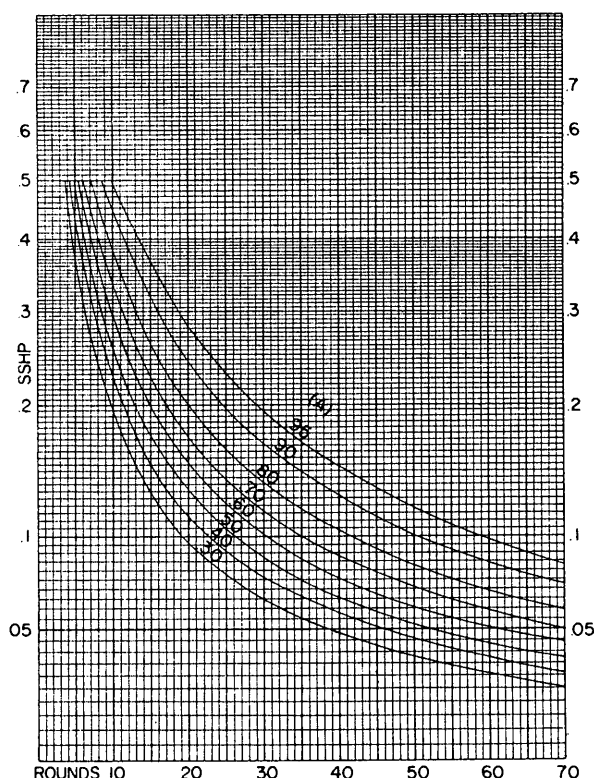


Figure 129. Assurance of at least three hits for "N" rounds when single shot hit probability is known.

c. For example, determine the assurance of getting at least 1 hit of 20 rounds when the SSHP is 0.045. (Answer: .60, fig. 127.) Determine the number of rounds required for at least two hits when the SSHP is 0.08 and the desired assurance is 0.70. (Answer: 30 rounds, fig. 128.)

d. Although it is impossible to be certain of the number of rounds needed to hit or destroy a target, use of the graphs will permit an approximation. Probability (assurance) is a substitute for fact, and, until the fact is actually known, probability provides the best guide as to what to expect. Unfortunately, the SSHP and assurance levels are usually less than the ones derived from the method in *a* through *c* above, because the center-of-impact usually is not at the center of the target as assumed. For example, an apparent center-of-impact located by the mean of 12 rounds is more accurate than one located by the mean of only 6 rounds. An

estimate of the probable error of the center-of-impact as a function of the number of rounds from which it was determined can be found by multiplying the firing table probable error by the appropriate factor shown below.

Number of rounds	Factor
2	0.7
4	0.5
6	0.4
8	0.4
10	0.3
12	0.3
14	0.3
16	0.3
18	0.2
20	0.2

e. In the example shown in paragraph 551c for the 8-inch howitzer, if the adjusted data of the center-of-impact were based on 6 rounds, then the range probable error of the center-of-impact at that time would be 7 meters ($0.40 \times 18 = 7.20$). This has the effect in SSHP computations of an apparent increase in the weapon probable error. The magnitude of the apparent weapon PE is approximately equal to the square root of the sum of the squares of the weapon PE and the center-of-impact PE or, in this case, $(18)^2 + (7)^2$, which equals 19 meters to the nearest meter. Hence, 19 meters would be used in the place of 18 meters in the computation of single shot hit probability. If the target is to be attacked without adjustment, the apparent weapon PE is assumed to be twice the weapon probable error. The deflection PE can be found in a similar manner although the change will normally not be significant. The method outlined above is valid for only one round in fire for effect. Thus, it is not to be used with the assurance graphs.

555. Developed Probable Error

Firing tables indicate the probable errors of a cannon in various dimensions (range, deflection, height of burst, and time of burst). By using round-to-round data from center-of-impact registrations and fall of shot calibrations, a positive check is available on the performance of cannons and crews. The developed probable error can be approximated by multiplying the maximum dispersion observed (longest range

minus shortest range) in a group of rounds by the appropriate factor from the following tabulation (n is the number of rounds in the group).

<i>n.</i>	<i>Factor</i>
2 -----	0.60
3 -----	0.39
4 -----	0.33
5 -----	0.29
6 -----	0.27
7 -----	0.25
8 -----	0.24
9 -----	0.23
10 -----	0.22
11 -----	0.21
12 -----	0.21

For example, the maximum observed range dispersion in a group of eight rounds is 150 meters. The approximate developed range probable error is 36 meters to the nearest meter ($0.24 \times 150 = 36.0$).

556. Summary

a. The artilleryman needs knowledge of probabilities to estimate properly the accuracy and effectiveness of fires which are planned and to evaluate fire that has been delivered.

b. Probability is no more valid than the data from which it is deduced. Probable errors in locating the center-of-impact with respect to the target reduce SSHP and assurance. Each projectile or missile deviates from its own center of impact according to normal distribution; the center-of-impact must be estimated and computations continued from there.

c. Probability tables and pertinent graphs simplify applying statistical methods to artillery fires; however, proper use of these tables and graphs requires a true picture of the problem at hand. To set up a problem in probability, the law of probability and characteristic dispersion patterns must be known.

d. Probabilities associated with the firing of successive volleys are combined with lethal areas and disposition of specific targets to serve as a guide toward a more intelligent selection of weapons and ammunition in the attack of targets (ch. 30).

e. The distinction between accuracy and precision must be recognized. Firing table probable errors define precision; that is, the magnitude of the dispersion pattern around the mean. They do not define accuracy completely but only a part of it. Accuracy is defined by the combined probable errors of all the elements used in computing or deriving firing data. For example, the accuracy of K-transfers depends on the accuracy of survey, target location, current registration corrections, laying, normal dispersion, etc. Also, the accuracy of met plus VE transfers depends on accuracy of survey, target location, met data (at the time and place used), the VE used, laying, etc. Accuracy, therefore, is affected by many contributing sources of error. To predict correctly the accuracy of contemplated fire, the probable errors of all applicable elements must be known and combined into what is known as a systems probable error. The method for combining several independent probable errors is to express them in a common unit of measure (e.g., meters), square these values, add all of the squares, and then take the square root of this sum. For practical purposes, the systems probable error is twice the firing table probable error. It is not the purpose of this manual to define the magnitude of these separate sources of error. The purpose is only to point out the fact that the firing table probable error is only one of many sources of error which affect accuracy.

f. For a more detailed discussion of dispersion and probability, see FM 6-141.

CHAPTER 30

TARGET ANALYSIS AND ATTACK

Section I. FACTORS INFLUENCING ATTACK OF TARGETS

557. General

The commander or his designated gunnery officer must consider certain factors when deciding to attack a target or when planning fires. Conformity to the scheme of maneuver of the supported troops and evaluation of the enemy are factors of primary concern. For detailed information concerning field artillery tactics, see FM 6-20-1. For detailed information concerning non-nuclear lethality and effects, see FM 6-141.

558. Nature of Target

The method of attacking a target depends largely on the nature of the target. The nature of the target includes type, size, density, cover, mobility, and importance. To determine the proper type of projectile, fuze, caliber of weapon, and necessary ammunition expenditure, the observer and the S3 must consider carefully the nature of the target. The nature of the target is also a guiding factor in determining the type of adjustment and the speed of attack.

a. Fortified targets or armor must be destroyed by precision fire, assault fire, or direct fire using projectiles and fuzes appropriate for penetration. The highest practicable charge should be used in assault and direct fire to increase penetration and to decrease vertical dispersion. The charge with the smallest PE_r should be used in precision fire to decrease horizontal dispersion. If the target is flammable, shell WP should be mixed with shell HE—WP to ignite materiel and HE to cause fragmentation.

b. A target consisting of both personnel and materiel is normally attacked by area fire, using

air or impact bursts to neutralize the area. The selection of caliber, projectile, and fuze is influenced by the extent of damage to the materiel desired.

c. Armored or fortified targets must be destroyed by precision fire, assault fire, or direct fire using projectiles and fuzes appropriate for penetration. The highest practicable charge should be used to increase penetration and to decrease dispersion. If the target is flammable, shell WP should be mixed with shell HE—WP to ignite a fire and HE to cause fragmentation.

d. Since the precision with which the observer (or other target acquisition agency) can determine the dimensions of the target is limited and because area targets are seldom precisely delineated, it is convenient to adopt standard terms for target reporting.

(1) *Target depth.* All area targets are assumed to be approximately 250 meters in depth; 250 meters is also the depth of three volleys from a 105-mm howitzer battery and is approximately the depth of a single volley from a 155-mm howitzer battery. Targets greater than 300 meters in depth may be attacked as two targets. To achieve a standard depth, no special corrections are required.

(2) *Scales.* Three scale designations for targets have been selected.

(a) *Scale 0.* Scale 0 designates those targets ranging from a virtual point to approximately 100 meters in width. Scale 0 targets can be assumed to be 75 meters wide. It is assumed that a parallel or open sheaf of any caliber will more than

cover a scale 0 target. If the center-of-impact is adjusted on the target, ammunition will be wasted during fire for effect with a parallel or open sheaf. However, speed or a situation in which it cannot be predicted that the center-of-impact will fall on the center of the target (e.g., unobserved fires) may dictate the use of a parallel or open sheaf with scale 0 target. If an observer is adjusting on a scale 0 target, he will normally converge the sheaf.

- (b) *Scale 1.* Scale 1 targets are those that are wider than scale 0 and up to 300 meters in width; that is, scale 1 targets are assumed to be 250 meters in width. This figure has been chosen because it bears a convenient relationship to the effective front covered by the parallel sheaf of a 105-mm, 155-mm or 8-inch howitzer battery.
- (c) *Scale 2.* Scale 2 targets are those assumed to be greater than 300 meters and up to 450 meters in width; that is, scale 2 targets are assumed to be 350 meters in width. This figure has been chosen because it represents the effective front covered by the 105-mm, 155-mm or 8-inch howitzer battalion firing one volley, parallel sheaf, at the target center.
- (3) *Standard target sizes.* Standard target sizes of any dimensions may be adopted to satisfy conditions encountered. The dimensions of a target are needed for computations to determine the type and volume of fire to procure specified results. A few fixed sizes meet the requirement.

559. Results Desired

The method of attacking a target is influenced by the results desired. Results are of four types, which, by their description, furnish a guide for the method of attack.

a. *Destruction Fire*—fire concentrated on materiel which is to be damaged to such an extent that it is rendered useless.

b. *Neutralization Fire*—fire delivered for the purpose of reducing the combat efficiency of enemy personnel by hampering and interrupting the fire of weapons, by reducing the freedom of action of the enemy, by reducing the ability of the enemy to inflict casualties on our troops and by severely reducing the movement of the enemy within an area. Most artillery fire missions seek to neutralize the target. Neutralization is often maintained by following the initial fires with repeated fires of less intensity at varying intervals.

c. *Harassing Fire*—fire of less intensity than neutralization fire, designed to inflict losses or, by the threat of losses, to disturb enemy troops, to curtail movement, and to lower morale.

d. *Interdiction Fire*—fire placed on an area or point to prevent the enemy from using the area or point for that period of time deemed necessary. Interdiction fire is usually of less intensity than neutralization fire.

560. Registration and Survey Control

a. Effective transfers are accomplished best when data from survey and current registrations are available or when current met messages and muzzle velocity data are available. When survey, registration, and met data are not available or are inadequate, targets should be attacked with observed fires since, in such cases, unobserved fires may be ineffective.

b. To the extent possible, surveillance should be obtained on all missions to determine the results of fire for effect. Accurate fire for effect without adjustment is highly effective against targets which contain personnel or mobile equipment. All destruction missions and missions fired at moving targets must be observed and fire for effect adjusted to the target.

561. Area To Be Attacked

a. The size of the area to be attacked may be determined by the actual size of the target or by the area in which the target is known or suspected to be. This information is usually an

estimation and is obtained from observer's reports, photographic interpretation, intelligence agencies, and experience in similar situations. The size of the area to be attacked is an important factor to be considered in the selection of units to fire (para. 564b).

b. Normally, a battalion should not fire with a range spread greater than 1 C (100 meters), since a greater spread will not give uniform coverage of the target. When choosing the range spread to be used, the S3 should consider the probable error, lethality, and effect desired.

562. Maximum Rate of Fire

a. The greatest effect is achieved when surprise fire is delivered with maximum intensity. Intensity is best secured by massing the fires of several batteries or battalions using time-on-target (TOT) procedures. The intensity of fires available by firing many volleys from a few units is limited by the maximum rate of fire (b below).

b. The maximum rates of fire shown in table VII are guides. These rates cannot be exceeded without danger of barrel heat igniting the propelling charge or damaging the tube. To maintain these rates (either to maintain neutralization on one target or to attack a series of targets), it is important that the pieces be rested or cooled from previous firing. The lowest charge possible should be used during periods of prolonged firing, since heating is more pronounced with the higher charges.

Table VII. Maximum Rates of Fire-Rounds Per Piece

Weapon	Maximum	Sustained
105mm How		
M52A1	4 rds/min, 1st 4 min	100 rds/hr
M101A1	4 rds/min, 1st 4 min	100 rds/hr
M102	To be determined	
M108	10 rds/min, 1st 3 min	180 rds/hr
155mm How		
M44A1	3 rds/min, 1st 3 min	60 rds/hr
M114A1	3 rds/min, 1st 3 min	60 rds/hr
M109	4 rds/min, 1st 3 min	60 rds/hr
175mm Gun		
M107	1.5 rds/min, 1st 3 min	30 rds/hr
8-Inch How		
M55	1 rd/min, 1st 3 min	30 rds/hr
M110	1.5 rds/min, 1st 3 min	30 rds/hr
M115	1 rd/min, 1st 3 min	30 rds/hr

563. Amount and Type of Ammunition

a. The amount of ammunition available is an important consideration in the attack of targets. The available supply rate will not be exceeded except by authority of higher headquarters. When the available supply rate is low, for example, 10 to 30 rounds per weapon per day for a 105-mm howitzer, missions should be limited to those which contribute the most to the mission of supported troops. When the available supply rate is high, missions fired may include missions which may affect planned or future operation and some missions which require massing of fires without adjustment.

b. The selection of a charge with which to attack a target depends on the range, terrain, and type of ammunition. To insure that the target can be reached, the maximum range of the charge selected for an adjustment should be at least one-third greater than the range to the target, when data are obtained by approximate methods, and one-eighth greater than the range to the target, when data are obtained by precise methods. If possible, a charge giving an elevation to the target of between 240 and 460 mils should be selected for howitzers. For flat trajectory weapons, there is a greater overlap in charges and no specific rule can be applied.

c. The type of ammunition selected to attack a target depends on the nature of the target and the characteristics of the ammunition available for the cannon to be used.

d. Effect of HE ammunition with various fuzes:

- (1) Since the effective fragmentation of impact HE projectile is greatest if it lands on hard ground at a large angle of impact, the lowest charge that can be used without excessive dispersion will give the greatest effective fragmentation (fig. 130). When the projectile passes through trees, the detonation may occur in the foliage and effectiveness may be either improved or lost, depending on the density of the foliage. And nature of the target.

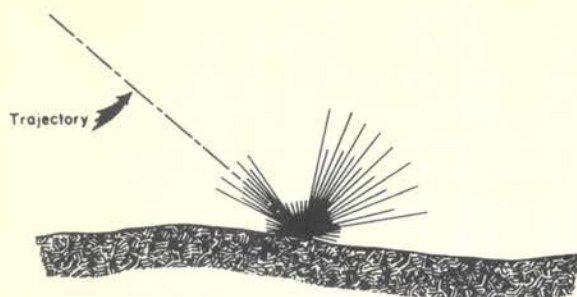


Figure 130. Effect of impact burst with fuze quick.

- (2) The three types of fuzes that are used with HE ammunition to obtain airbursts are proximity (VT), time, and delay fired to ricochet. They are listed in order of effectiveness.

(a) *Fuze VT.* Fuze VT detonates automatically on approach to a terrestrial object. Fuze VT is used to obtain airbursts (fig. 131) without the necessity of adjusting height of burst. If the VT element fails to function, fuze quick action occurs on impact. The height of burst of fuze VT varies with the slope of fall and with the terrain in the target area. If the terrain surrounding the target area is wet or marshy, the height of burst will be increased. Light foliage has little effect on VT fuze, but heavy foliage will increase the height of burst by about the height of the foliage. However, if the slope of fall is steep, most bursts will occur below the treetops. Since it is not limited by range and because the height-of-burst probable error is smaller, VT fuze is preferable to time fuze for targets which are at long ranges, which require high-angle fire, or which must be attacked at night. The greater the slope of fall, the closer the burst will be to the ground. In firing close to friendly troops, the lowest practicable charge should be used to obtain a steep angle of fall.

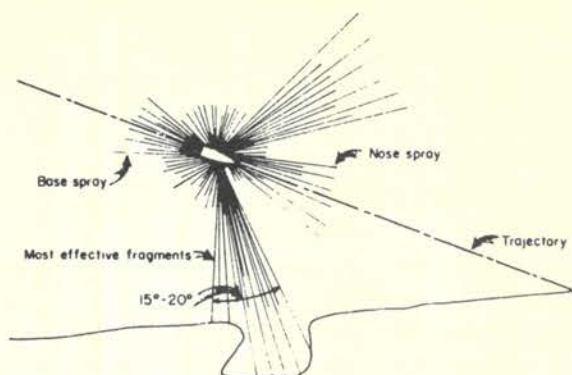


Figure 131. Effect of air burst with VT or time fuze.

- (b) *Fuze time.* Airbursts may be obtained by the use of fuze time (fig. 131). The height of burst is determined by the quadrant elevation, charge, and fuze setting. If the time element fails to function with fuze time, fuze quick action occurs on impact. With fuze time, the height of burst can be adjusted, but, because of dispersion, not all bursts will be at the desired height. The highest practicable charge should be used with fuze time to minimize the height-of-burst probable error. A height-of-burst probable error greater than 15 meters is considered excessive.
- (c) *Fuze delay.* Fuze delay may be used to obtain airbursts by ricochet. If the angle of impact is small and the surface it strikes is firm, the projectile will ricochet before detonating and produce airbursts (fig. 132). Because of the uncertainty of ricochet actions, fuze delay to obtain ricochets should not be fired without observation. The highest practicable charge should be used to obtain ricochet bursts with fuze delay. If the angle of impact is too great, the projectile will penetrate before detonating, producing camouflet action (fig. 133). Fuze delay can be used to destroy earth and

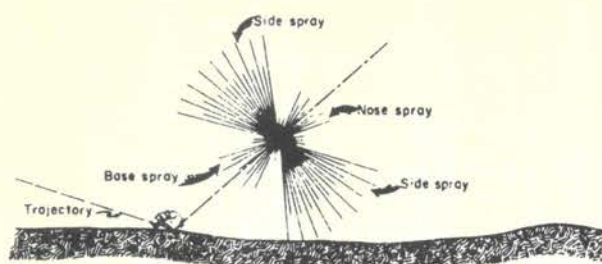


Figure 132. Effect of air burst with fuze delay (ricochet).

log fortifications and is effective against some masonry and concrete. Fuze delay should not normally be used against heavy armor.

- (3) Greater penetration against masonry or concrete can be obtained with HE ammunition by using a concrete-piercing fuze (CP). There are two types of concrete-piercing fuze: Non-delay, used primarily for adjustment, and delay, used for fire for effect because it gives the greater penetration. HEAT (high explosive, antitank) am-

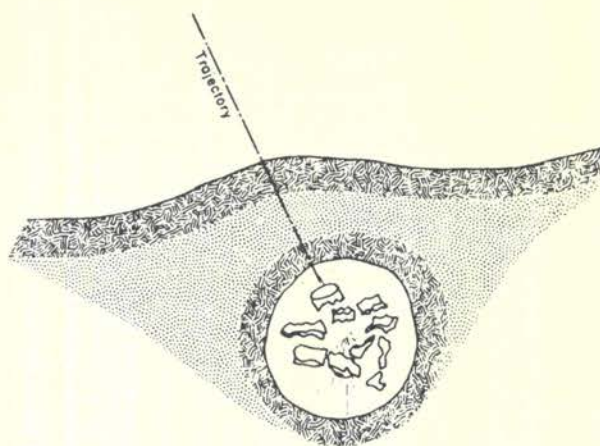


Figure 133. Camouflet action, fuze delay.

munity can be used against reinforced concrete or heavy masonry. HE projectile with fuze delay is used at intervals to clear away rubble and blow apart shattered fragments. The effectiveness of various caliber weapons against concrete is shown in table VIII.

Table VIII. Effect on Concrete

Cannon and projectile (maximum charge)	Thickness* of concrete perforated by single round (face perpendicular to line of impact) (cm)			Number of rounds, falling in circle of given diameter** necessary to perforate various thicknesses* of concrete at given ranges			
	Range (meters)			Thickness (meters)	Range (meters)		
	900	2700	3600		900	2700	3600
105-mm howitzer M2A1 and M4; HE M1, fuze M78 Series.	64	48	46	0.9 1.5 2.1	5 14 27	10 27 53	12 33 64
155-mm howitzer M1; HE M107, fuze M78 Series.	119	98	82	0.9 1.5 2.1	1 3 7	1 5 11	2 9 18
8-inch howitzer M2; HE M106, fuze M78 Series.	168	143	122	0.9 1.5 2.1	1 1 3	1 2 5	1 4 8

*Thickness perforated is based on a line of impact perpendicular to the surface. The effectiveness decreases rapidly when the line of impact is other than perpendicular to the surface. Ricochets will occur when the line of impact is 20° to 35° or more from the perpendicular. The higher the striking velocity, the greater the angle may be before ricochet occurs. After the surface has been chipped, the angle may be still greater.

**Diameter of circles used as a basis for data.

105-mm howitzer ----- 0.9 meters
155-mm howitzer ----- 1.2 meters
8-inch howitzer ----- 1.5 meters

e. Ammunition for Attacking Armor Targets.

- (1) High explosive, antitank (HEAT) projectiles are available for 105-mm howitzers. The projectile contains a shaped charge. It is propelled by a fixed charge.
- (2) At ranges up to 1,400 meters, HEAT projectiles will penetrate 10 centimeters (cm) of armor plate when the line of impact is perpendicular to the surface of the armor.
- (3) HEAT ammunition is relatively ineffective against personnel in the open because of the small amount of fragmentation. Bursts are difficult to observe. HEAT ammunition is more effective at short ranges and is normally fired by direct laying. Adjustment of indirect fire, when necessary, is conducted with HE ammunition until fire for effect is commenced.
- (4) The 155-mm howitzer and larger weapons using HE ammunition with

fuze quick, are effective against armor in the direct fire role because of the size and explosive power of the projectile.

f. Chemical Ammunition. Chemical ammunition is used for producing casualties, screening, and marking. Among the types of fillings in chemical projectiles are toxic agents, white phosphorus, smoke HC, and colored smoke.

- (1) Projectiles filled with toxic agents are particularly useful for causing casualties in fortified positions or installations. See FM 3-10 for detailed information on the use of chemical projectiles. Toxic chemicals may be used at low expenditure rates to harass the enemy and require them to wear protective masks for prolonged periods.
- (2) The influence of weather (wind direction and speed, temperature, and temperature gradient) has a great deal to do with the effectiveness and tactical desirability of chemical agents. If favorable weather

conditions exist, toxic agents will be more effective than HE on a round for round basis.

564. Consideration in Selection of Units to Fire

a. The unit selected for a mission must have cannons of the proper size and caliber to cover the target area quickly, effectively, and economically. Many targets are of such size as to allow a wide choice in the selection of the number of batteries or battalions to be used. If the unit selected to fire cannot mass its fire in an area as small as the target area, ammunition will be wasted. Conversely, if a unit can cover only a small part of the target area at a time, surprise is lost during the shifting of fire and the rate of fire for the area as a whole may be insufficient to secure the desired effect. The decision of whether to have many units firing a few volleys on a large target or a few units firing many volleys is often a critical one (*b* below).

b. Many overlapping factors affect the selection of units and the number of volleys to fire on a target. Some of these factors are—

- (1) *Availability of artillery.* When the number of available artillery fire units is small, more targets must be assigned to each artillery unit.
- (2) *Size of the area to be covered.* The size of the area to be covered must be compared to the effective depth and width of sheaf to be used by the battery or batteries available.
- (3) *Increased area coverage.* Targets greater than 120 meters in depth and greater in width than the standard sizes discussed in paragraph 558*d* can be covered by—
 - (*a*) Increasing the number of batteries firing.
 - (*b*) Dividing the target into several targets and assigning portions to different batteries.
 - (*c*) Shifting fire laterally or using zone fire with a single battery or with a

number of batteries controlled as a single fire unit.

- (4) *Caliber and type of unit.* The projectiles of larger calibers are more effective for destruction missions. High velocity guns are desired for maximum penetration of fortifications.
- (5) *Suprise.* For surprise, a few volleys from many pieces are preferable to many volleys from a few pieces.
- (6) *Accuracy of target location.* Certain important targets which are not accurately located may justify the fire of several units to insure coverage.
- (7) *Critical targets.* The emergency nature of certain targets may justify the use of all available artillery fire. Enemy counterattack formations are such targets.
- (8) *Dispersion.* At extreme ranges for a given cannon and charge, fire is less dense. More ammunition is required to effectively cover the target. Extreme ranges may require the selection of a unit to fire along the long axis of the target in order to obtain the maximum effect from dispersion. At normal elevations (240 to 460 mils), probable error and dispersion do not present a serious problem and should concern the S3 only when firing near maximum range.
- (9) *Maintenance of neutralization and interdiction.* Neutralization and interdiction fires may be maintained by the use of a few small units rather than all units which fired for effect. A unit may be able to fire other missions during the same period it is maintaining neutralization or interdiction fires.
- (10) *Vulnerability of targets.* Some targets should be attacked rapidly with massed fire while they are vulnerable. Such targets are truck parks or a large number of personnel in the open.

565. Technique of Attack

The technique of attack is determined by an analysis of the capabilities of the cannons and ammunition available and the terrain of the target area. High-angle fire may be needed to fire into or out of defiladed positions. Direct or indirect fire with mobile, heavy caliber cannons is used for destruction missions when possible. In destruction missions, guns are usually preferred for short ranges and howitzers for long ranges.

566. Typical Targets and Methods of Attack

a. Enemy materiel, fortifications, and personnel in sufficient numbers to justify ammunition expenditure are generally artillery targets, except—

tion expenditure are generally artillery targets, except—

(1) *Minefields*. HE ammunition is ineffective for clearing minefields. The mines are detonated only by direct hits. Artillery fire fails to clear the minefields and only creates more of a problem in locating and removing the mines by hand, and in moving equipment across the mined area.

(2) *Barbed wire*. The employment of artillery to breach wire requires extravagant use of ammunition.

b. Table XIII lists typical targets and suggests methods of attack.

Table XIII. Typical Targets and Suggested Methods of Attack
(Located in back of manual)

Paragraphs 567 through 571 rescinded.
Figures 134 through 142 rescinded.
Tables IX, X, XI, XII rescinded.

CHAPTER 31

SERVICE PRACTICE

Section I. SERVICE PRACTICE PROCEDURES

572. General

a. Service practice is a practical exercise in which all elements of the gunnery team are trained in the use of service ammunition. **Each service practice should begin with a tactical situation given by the officer in charge of firing.** The primary purpose of service practice is to train artillerymen to adjust artillery fire. Fire direction personnel and the firing battery are also trained in their duties during service practice. Prescribed gunnery procedures and techniques should be used, except when judgment clearly indicates that a departure from normal procedure will expedite the mission.

b. Service practice is part of the tactical field training of field artillery units. All elements of training, to include mobility, communication, tactical employment, and conduct of fire, should be combined in the service practice.

c. A service practice is an instructional medium and should be conducted with the same briskness and precision as any military drill. The officer in charge of firing must make full use of the service practice and allow no lulls in the exercise. Observers must conduct each mission in a brisk, businesslike manner.

d. This chapter will serve as a *guide* in training personnel in observer procedures for the conduct of fire.

573. Roles of Key Personnel

a. *Installation Commander.* The commanding officer of an installation is responsible for maintenance and assignment of firing ranges allotted to his command. He must insure that the safety precautions prescribed in AR 385-63 are followed. A range officer assists the commanding officer in all matters pertaining to firing ranges.

b. *Range Officer.* The range officer is responsible to the commanding officer for the preparation and maintenance of the firing ranges. Among his responsibilities are the preparation, authentication, and distribution of safety cards. The safety

card is prepared in accordance with AR 385-63.

c. *Officer in Charge of Firing.* The officer in charge of firing is responsible for all aspects of a training exercise that involves firing live ammunition. He is responsible for safety. Normally, he has safety officers to assist him.

d. *Safety Officer.* The safety officer at the firing point represents the officer in charge of firing. Orders issued by the safety officer that prohibit firing can be rescinded only by the officer in charge of firing. The safety officer should interfere as little as possible with the delivery of fire. The safety officer must not be detailed to check or correct errors in laying or servicing the pieces that do not affect safety. The safety officer will not be assigned any additional duties during firing.

574. Training Prior to Service Practice

a. The gunnery techniques and procedures involved in a service practice must be taught before the unit conducts service practice.

b. The service practice OP is not the place to learn conduct of fire procedure. **All procedures should be learned prior to going to the OP.** Familiarity with procedure can be attained by firing simulated missions. A simple and effective device for practicing simulated missions is the "matchbox problem." Matchbox problems require no equipment except a small object, such as a matchbox, and a piece of paper on which a mil scale has been drawn to represent the scale of the reticle in binoculars. Two or more persons should work together on these problems. The matchbox, which represents the target, is placed on a table or any convenient surface and the mil scale is placed on the table in front of the target (fig. 143). The person acting as observer, facing the target and mil scale, announces the fire request and OT distance to the second person, who stands beside the table and announces the fire order and ON THE WAY. After announcing ON THE WAY, the person at the table places the top of a pencil on the table for a moment to simulate each burst.

The observer senses the burst or volley, using the mil scale **for measuring deviation**, and gives his next command. This procedure is continued until the mission is complete. The person at the table critiques the mission and changes places with the person acting as the observer.

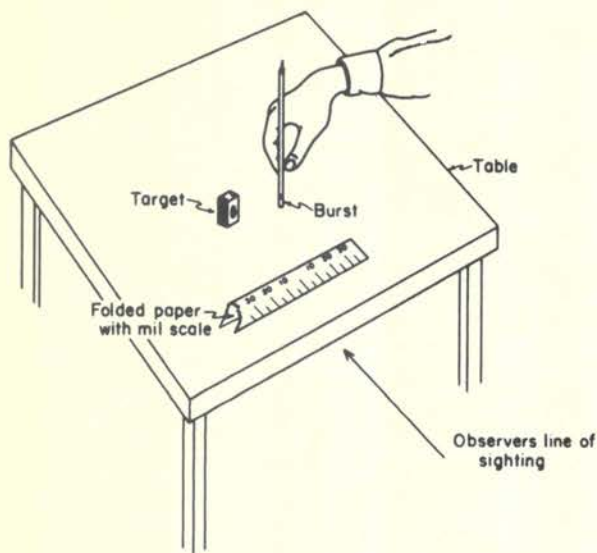


Figure 143. Matchbox problem setup.

575. Preparation for Service Practice

Well in advance of the scheduled service practice, the officer in charge should—

a. Make a ground reconnaissance of the area. Select the observation post (OP) to give the desired angle T and observation.

b. Prepare a map and plot the locations of the batteries, observation post, safety limits, and the registration points.

c. Select appropriate reference points and targets.

d. Obtain the safety card from the range officer. One copy of the approved safety card must be delivered to the safety officer(s) prior to the service practice and one copy retained by the officer in charge of firing. The officer in charge of firing must check the safety cards and, if they are not correct, attain a reconciliation through the range officer.

576. Procedures at the Observation Post

a. The officer in charge of firing must arrive sufficiently in advance of the participating per-

sonnel to insure that the observation post is properly organized. Figure 144 depicts a typical nontactical observation post arrangement. Preparation must include, but need not be limited to, a thorough check of communications, a check of range control to insure that the range is clear, and organization of the observation post to insure that all observers have a good view of the target area.

b. An orientation on the terrain must be given to all observer personnel and should include the limits of the target area. A good method is to describe a tactical situation involving location of friendly troops, zones of action, and final objective. For subsequent target designation, the orientation should define reference points and the azimuth for one or more of the points. If possible, these points should be on the horizon and not more than 200 mils apart.

c. The observers should be given pertinent parts of the battery executive's report and any information available at the fire direction center which will assist them in requesting fire. Types of fuzes and projectiles available should not be given at this time. The observer should be told to consider all types of fuzes and projectiles authorized in the basic load in selecting the ammunition for his mission.

577. Designation of Targets

a. Targets should be designated in a uniform manner. This enables the personnel to become accustomed to a routine and to devote their effort to making precise measurements. Targets should be designated by announcing their size, nature, and location relative to the nearest reference point and the skyline. The targets should be realistically described in a sound tactical location; e.g., observation post on a point that affords observation or mortars in defilade.

b. Target locations should be exact (deviations should be checked with a battery commander's telescope). Immediately prior to target designation, the officer in charge should verify his description of the target by using his field-glasses.

c. The nature of targets must be varied to cause observers to consider selection of proper fuze and projectile. The description should

depict a realistic target, the following are examples of proper designation of targets.

- (1) TO IDENTIFY TWO MORTARS FIRING, FROM THE LONE TREE GO LEFT 85 MILS, DOWN FROM SKYLINE AT THAT POINT 16 MILS. THIS WILL PLACE YOU ON YELLOW MATERIEL. THAT IS THE ADJUSTING POINT.
- (2) TO IDENTIFY A CAVE ENTRANCE, FROM MARKER GO LEFT 70 MILS AND DOWN FROM THE SKYLINE AT THAT POINT 12 MILS, WILL PLACE YOU ON A WHITE ROCK, THAT IS THE CAVE ENTRANCE.

d. In the selection of targets, careful consideration should be given to prescribed safety limits. No target should be assigned so close to a boundary that a reasonable bracket (200 meters) cannot be obtained. It is imperative that the officer in charge of firing insure that the first round fired will land in the impact area. When firing is to be conducted at long ranges and under unfavorable weather conditions, the range error resulting from velocity error and effects of met conditions may at times exceed 1,000 meters. This potential error also makes the use of time fire hazardous until after registration corrections are obtained. The best data available should always be used.

e. After the target has been identified, the observer should be given enough time to prepare initial data; early in training, 2 minutes is normally adequate. To create an air of realism, the first mission should be fired against a target of opportunity. Registration can follow. For safety reasons, targets selected prior to a registration should be located near the center of the impact area. All observer personnel should prepare initial data for each mission and keep a record of the missions fired.

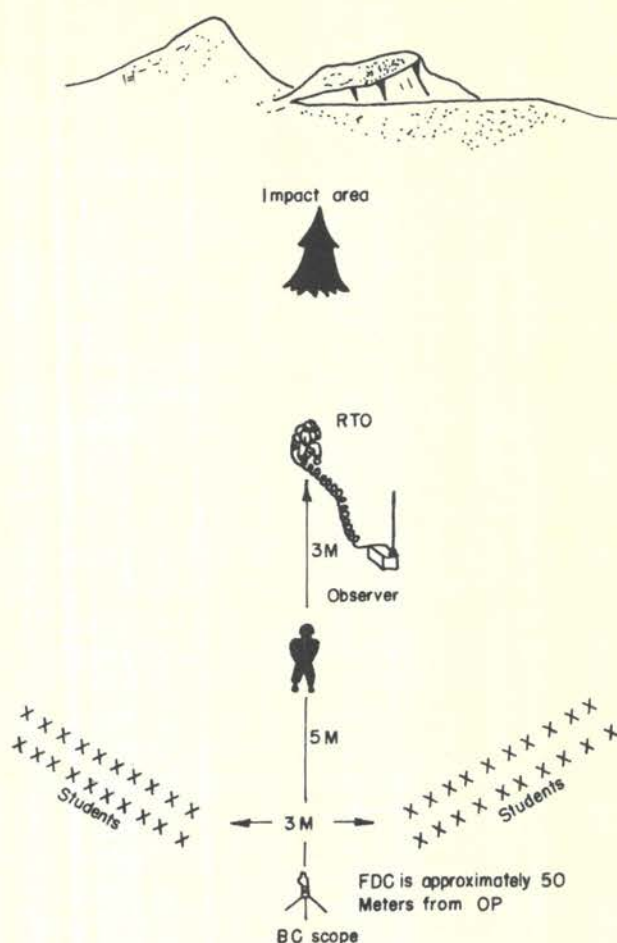


Figure 144. Typical nontactical observation post
gement.

578. Supervision of Firing

a. The officer in charge must instill confidence in the observer personnel and arouse and maintain their interest in the service practice. He must take maximum advantage of time and ammunition to teach proper observer procedures. The officer in charge must enforce silence on the observation post during a mission so that the observer is not distracted.

b. The observer must understand that the

successful completion of the fire mission is his responsibility. A good policy is for the officer in charge not to interfere with the conduct of a mission unless safety is jeopardized or repeated errors are made which, if continued, would decrease the instructional value of the mission. In such cases, the officer in charge may give help, or he may reassign or stop the mission.

c. The observer should be required to announce his sensings promptly and clearly. The observer must sense the burst as soon as it occurs. The officer in charge should stress that accurate firing data depends on accurate observer sensings and corrections.

579. Critiques

The officer in charge should conduct a constructive and impersonal critique immediately after each mission. The critique should be specific, limited to essentials, and conducted generally in the following order:

- a. A restatement of the assigned mission.
- b. A statement that the mission was completed in a satisfactory (unsatisfactory) (excellent) manner or was not completed.

Section II. STANDARD TIMES FOR ARTILLERY FIRE

581. General

The mission of the artillery is to deliver accurate and timely fire in support of infantry and armor. To accomplish the mission, certain standards of accuracy and speed must be met. Total times required for a mission measure the efficiency of a unit as a whole. A continuous program of timing by commanders should assist in locating and eliminating time losses. The ultimate goal must be to reduce the time required for the will-adjust mission to the absolute minimum in order to make it closely approximate the effectiveness of fire without adjustment. This can be done if commanders will constantly stress the necessity for timely determination of accurate initial data and the smooth, efficient functioning of all members of the artillery team.

582. Fire Mission Phases

The will-adjust mission is only a substitute for the more effective surprise mission. The will-adjust mission results in a loss of surprise and, consequently, the kill capabilities of a sudden volume of accurately placed fire. Adjustment

c. A concise analysis of the mission. Stress points of instructional value. State the good points of the mission and the undesirable features. Point out violations of procedure. Stress that adhering to prescribed procedures will always bring good results. Make recommendations for improvements. The analysis should follow the sequence of the mission, but it should not be a round-by-round discussion.

d. A request for comments or questions.

580. Other Considerations

Service practices should be conducted from various observation posts with different impact areas being used. Periodically, service practice with maximum range and large angle T should be conducted to acquaint observers with the effects of dispersion. **As the observer becomes proficient in the adjustment of fire, service practice should be conducted from tactical observation posts. Grading should include: Selection of approach routes, use of cover and concealment, and firing of the mission.**

requires a longer use of wire and radio communication, thus inviting enemy jamming of radio and overloading of wire lines. In addition, as time for firing increases, exposure time to enemy counterbattery measures is increased. The will-adjust mission can be divided into three phases—first, the initial data phase; second, the adjustment phase; and third, the fire for effect phase.

a. The *initial data phase* starts when a target is seen or identified and ends when the first round of adjustment is on the way. During this phase, the target has not been alerted and urgency will depend on the nature of the target. For example, a target such as a column of infantry proceeding toward a point requires faster reaction than a target such as a command post. More time spent in this phase may reflect better initial data and, consequently, less time and fewer volleys for completion of the mission. However, during training under service practice conditions, stress must also be placed on speed in the initial data phase to emphasize the importance of speed in accomplishing the artillery mission.

b. The *adjustment phase* starts when the initial round or volley lands near the target. From that instant on, the target is warned and evasive action can and will be taken.

c. The *fire for effect phase* starts when the observer commands FIRE FOR EFFECT and ends with completion of the mission. The fire for effect rounds should normally follow the last rounds of adjustment as quickly as possible.

583. Standards of Proficiency

a. Timing standards should only be used as a guide in measuring the overall efficiency of a field artillery unit. Accuracy must not be sacrificed to obtain speed. Faster adjustments and reduction of exposure time depend on—

- (1) Improving initial data.
- (2) Decreasing the number of adjusting rounds or volleys required.

- (3) Speeding action of personnel through better training and elimination of lost motion.

b. The timing standards contained in table XIV are based on average terrain and weather conditions, impact fuze in adjustment, impact or VT fuze in fire for effect, a maximum of four volleys in adjustment, a time of flight not greater than 25 seconds, and observer distance of 3,000 meters or less. Although no standard times are given for weapons other than the 105-mm and 155-mm howitzers, the times listed can be used as a guide for all artillery pieces. The only change required will be to allow more time for loading and laying the larger cannons and usually for a longer time of flight.

Note. The standards in table XIV do not separate telephone and radio operator time intervals. The efficiency of operators can be judged by the number of read-backs required. If communication personnel are not efficient, the total time standards will not be met.

Table XIV. Standards of Proficiency (Speed) for Artillery Fires

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds			
				Superior	Excellent	Very satisfactory	Satisfactory
	Observer---	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's initial fire request.)	Note 3	01 00	01 30	02 00	02 30
		Per volley, determination and transmission of corrections. (Time from last burst or volley to last element of observer's correction.)	Note 3	00 12	00 15	00 18	00 21
Area fire---	Fire direction center.	Plotting target and determination of firing data for initial volley. (Time from last element of observer's initial fire request to quadrant command to battery.)	Note 3	00 30	00 45	01 00	01 15
		Per volley, determination of firing data subsequent to initial volley. (Time from last element of observer's correction quadrant command to battery.)	Note 3	00 15	00 20	00 25	00 30
		Mass battalion after FFE is ordered by observer. (Time from observer's FFE to ON THE WAY for the last battery.)	Note 1	00 42	00 52	01 02	01 12
			Note 2	00 57	01 07	01 17	00 27
	Firing battery.	Initial volley in adjustment ----- (Time from FCD quadrant to ON THE WAY.)	Note 1	00 15	00 20	00 25	00 30
		Per volley, subsequent to initial volley ----- (Time from FCD quadrant to ON THE WAY.)	Note 2	00 30	00 35	00 40	00 45
		FFE, battery volley ----- (Time from FDC quadrant to ON THE WAY for the last round.)	Note 1	00 10	00 15	00 20	00 25
			Note 2	00 25	00 30	00 35	00 40
			Note 1	00 15	00 20	00 25	00 30
			Note 2	00 30	00 35	00 40	00 45
	Overall firing time.	Time from first ON THE WAY to ON THE WAY for the last round in FFE. (Based on four volleys in adjustment.) -----	Note 1	04 25	05 17	06 09	07 01
			Note 2	05 25	06 17	07 09	08 01
Precision fire.	Observer	Determination and transmission of initial data. (Time from last word of target identification to last element of observer's initial fire request.)	Note 3	01 00	01 30	02 00	02 30
		Per round, determination and transmission of corrections. (Time from burst to last element of observer's correction.)	Note 3	00 10	00 13	00 16	00 19
		Per round in FFE, determination and transmission of sensing. (Time from burst to last element of observer's sensing.)	Note 3	00 08	00 11	00 14	00 17
	Fire direction center.	Plotting target and determination of firing data for initial round. (Time from last element of observer's initial fire request to quadrant command to battery.)	Note 3	00 30	00 45	01 00	01 15
		Per round, determination of firing data subsequent to initial round. (Time from last element of observer's correction to quadrant command to battery.)	Note 3	00 15	00 20	00 25	00 30
	Firing battery.	Initial round in adjustment ----- (Time from FDC quadrant to ON THE WAY.)	Note 1	00 15	00 20	00 25	00 30
		Per round, subsequent to initial round, including FFE.	Note 2	00 30	00 35	00 40	00 45
			Note 1	00 10	00 15	00 20	00 25
			Note 2	00 25	00 30	00 35	00 40
	Overall problem time.	Adjustment only ----- (Time from first ON THE WAY to ON THE WAY for first round in FFE (based on four rounds in adjustment).)	Note 1	04 00	04 52	05 44	06 36
			Note 2	05 00	05 52	06 44	07 36

Table XIV. Standards of Proficiency (Speed) for Artillery Fires—Continued

Type of fire	Element	Event timed	Weapon	Standards—minutes and seconds			
				Superior	Excellent	Very satisfactory	Satisfactory
CI or HB registration.	Overall firing time.	Per round fired -----	Note 1	01 00	01 15	01 30	01 45
		(Time from ON THE WAY to next ON THE WAY. Includes report of instrument readings from two OP's.)	Note 2	01 15	01 30	01 45	02 00
		Total registration time -----	Note 1	07 00	08 45	10 30	12 15
		(Time from first ON THE WAY to last OP report of registration.)	Note 2	08 45	10 30	12 15	14 00
Fire for effect without adjustment.	Overall problem time.	Battery mission -----	Note 1	00 45	01 00	01 15	01 30
		(Time from last element of fire request to ON THE WAY.)	Note 2	01 00	01 15	01 30	01 45
		Battalion mission -----	Note 1	00 57	01 12	01 27	01 42
		(Time from last element of fire request to ON THE WAY for last battery to fire.)					

Note 1—105-mm howitzer.

Note 2—155-mm howitzer.

Note 3—Both 105-mm and 155-mm howitzers.

c. Table XV is a detailed breakdown of timing averaged for the "excellent" column, for area fire, in table XIV.

Table XV. Service Practice Timing

From—	To—	Time interval (in seconds)
Target identified.....	Observer ready with initial fire request (IFR).	74
Observer starts IFR....	Observer completes IFR....	16
Observer completes IFR.	Deflection sent to pieces (XO).	38
Deflection sent to pieces (XO).	Quadrant sent to pieces (XO).	7
Quadrant sent to pieces (XO).	Quadrant announced to chief of section.	5
Quadrant announced to chief of section.	Chief of section reports READY.	13
Chief of section reports READY.	Pieces are fired.....	2
(Pieces are fired).....	(ON THE WAY announced to observer.)	(4)
Target identified.....	Pieces are fired.....	155
Initial volley bursts in target area.	Observer completes subsequent fire request.	15
Observer completes subsequent fire request.	Deflection sent to pieces (XO).	14
Deflection sent to pieces (XO).	Quadrant sent to pieces (XO).	6
Quadrant sent to pieces (XO).	Quadrant announced to chief of section.	4
Quadrant announced to chief of section.	Chief of section reports READY.	8
Chief of section reports READY.	Pieces are fired.....	3
Initial volley bursts in target area.	Subsequent volley or fire for effect volley is fired.	50

CHAPTER 32

DUTIES OF THE SAFETY OFFICER

584. General

At all times, safety is a command responsibility. Under peacetime conditions, safety officers are required to assist commanders in satisfying this responsibility. The safety officer normally should be a regularly assigned officer of the battery at which he is functioning in order that there will be no divided responsibility between battery and battalion levels. Proficiency in the functioning of the safety officer should be treated in the same light as proficiency in the functioning of the battery executive. In either case, low standards dissipate the required sense of urgency and slow firing. The safety officer has two principal duties. First, he must insure that the pieces are laid and loaded so that the rounds, when fired, will land in the impact area. Second, he must insure that all safety precautions are observed at the firing point. While serving as safety officer, he will be assigned no other duties. In particular he will not be utilized to check the accuracy of the gun crews beyond that required to secure bursts in the designated impact area.

585. Duties of Safety Officer Before Firing

The duties of the safety officer before firing are as follows:

- a. Verify that the safety card applies to the unit, exercise, date, and time.
- b. Verify that the battery is in the position specified on the safety card.
- c. Prepare safety diagram.
- d. Check pieces for boresighting.
- e. Verify laying of the battery.
- f. Verify minimum quadrant elevations determined by the executive officer. Compare executive's minimum quadrant elevation with elevation for minimum range on safety diagram, using the larger of the two as the minimum quadrant elevation.
- g. Supervise the placing of safety stakes.
- h. Verify that ammunition to be fired is the type specified on the safety card.

i. Insure that chiefs of sections are informed of maximum and minimum quadrant elevations, right and left limits, and minimum fuze settings.

j. Visually check line of metal for parallel laying.

k. Verify that range clearance has been obtained.

l. Ascertain that visible portion of range is clear of personnel.

m. Insure that Department of the Army Regulations, post regulations, and local special instructions pertaining to safety are complied with.

586. Duties of Safety Officer During Firing

After his preliminary checks are made, the safety officer should indicate that from the point of view of safety the battery is ready to fire. Duties of the safety officer during firing are as follows:

a. Verify serviceability of ammunition.

b. Insure that charge, projectile, and fuze being fired are limited to those prescribed on the safety card.

c. Insure that rounds are not fired below minimum quadrant elevation nor above maximum quadrant elevation for the charge being fired.

d. Insure that rounds are not fired outside the lateral safety limits.

e. Insure that time fuze rounds are not fired with fuze settings below the minimum prescribed on safety diagram.

f. Instruct the executive officer not to fire until the safety officer has given a positive indication that it is safe to fire.

g. Command UNSAFE TO FIRE on all commands which are unsafe to fire and give all reasons therefor. Two examples are—

- (1) UNSAFE TO FIRE, 3 MILS OUTSIDE RIGHT SAFETY LIMIT AND 20 MILS ABOVE MAXIMUM QUADRANT ELEVATION.

(2) UNSAFE TO FIRE, 5 MILS BELOW MINIMUM QUADRANT ELEVATION.

h. Apply registration corrections to safety limits immediately after registration.

i. Report accidents and malfunctions of ammunition to the officer in charge of firing, request ambulance if needed, and be prepared to make a report as indicated in AR 700-1300-8.

j. Bring to the attention of the executive officer any unsafe conditions observed and suspend firing until they are corrected. Examples of unsafe conditions are—

- (1) Safety features of piece not operative.
- (2) Powder bags exposed to flames.
- (3) Personnel smoking near pieces.
- (4) Personnel handling ammunition improperly.
- (5) Fuzes and projectiles stored together.
- (6) Time fuzes previously set and not reset to safe.
- (7) Primer inserted before breech is closed (separate-loading ammunition).
- (8) Cannoneer failed to inspect powder chamber and bore after each round fired.
- (9) Cannoneer failed to swab powder chamber after each round of separate-loading ammunition fired.
- (10) Opening between lower cap and body of time fuze in excess of 0.014 inches (TB ORD 512).

587. Misfires (AR 385-63)

A misfire is sometimes the result of a mechanical failure and sometimes the result of a

human failure. Whatever the cause, when a misfire has occurred, the action required in AR 385-63 should be observed.

588. Safety Card

a. A safety card which prescribes hours of firing, the area where the firing will take place, the location of the gun position, limits of the impact area (in accordance with AR 385-63), and other pertinent data are approved by the range officer and sent to the officer in charge of firing. The officer in charge of firing gives a copy of the card to the safety officer, who constructs a safety diagram based on the prescribed limits.

b. There is no prescribed format for the safety card; however, the format shown below is generally used.

Safety limits for 155-mm how, sh HE, fz M520, M514

Firing point: 8632196586

Reference point GN Grid az—aprx: 0

Left limit: Az 4,730

Right limit: Az 5,450

Minimum range as measured but not less than 4,300 meters

Maximum range 8,000 meters

Special instructions: Use only chg 5 with this card: from az 4,730 to az 5,030, maximum range is 7,000 meters.

589. Safety Diagram

a. The safety officer, on receipt of the safety card, constructs a safety diagram. The diagram need not be drawn to scale but must accurately list the piece settings which delineate the im-

pact area; it serves as a convenient means of checking the commands announced to the gun crews against those commands which represent the safety limits. The diagram shows the right and left limits, expressed in deflections corresponding to those limits; the maximum and minimum quadrant elevations; and the minimum fuze settings (when applicable) for each charge to be fired. The diagram must not be cluttered with unnecessary information. Maximum fuze settings are not necessary, since a projectile fired with too great a fuze setting but with the proper maximum elevation would result in an impact burst within safety limits for range.

b. The basic safety diagram is a graphical portrayal of the data on the safety card. On the basic safety diagram are shown the minimum and maximum range lines; the left, right, and intermediate (if any) azimuth limits; the deflections corresponding to the azimuth limits; and the direction in which the battery is laid. The deflection limits are computed by comparing the azimuth on which the battery is laid to the azimuth limits and applying the difference to the referred deflection at which the aiming posts are emplaced.

Example: A 155-mm howitzer battery is laid on azimuth 5,100 and the aiming posts are set out at deflection 2,600. The safety card for the position occupied is that shown in paragraph 588b. The basic safety diagram for this situation is shown in figure 145.

c. Prior to registration, all rounds must be fired in the central portion of the impact area.

590. Minimum Quadrant Elevation (Low-Angle Fire)

The minimum QE is computed for each authorized charge. The minimum QE consists of the following elements.

a. *Site to Highest Point on Minimum Range Line.* The highest point on the minimum range line is determined by plotting the minimum range line on a map and inspecting the altitude of the highest point.

Note. If an isolated peak causes unnecessary limitation along the minimum range line, a separate site is computed, and only the firing in the immediate area of the peak is limited by the minimum quadrant elevation determined for the peak.

b. *Elevation for Minimum Range.* If corrections are known, they must be applied when the elevation is computed.

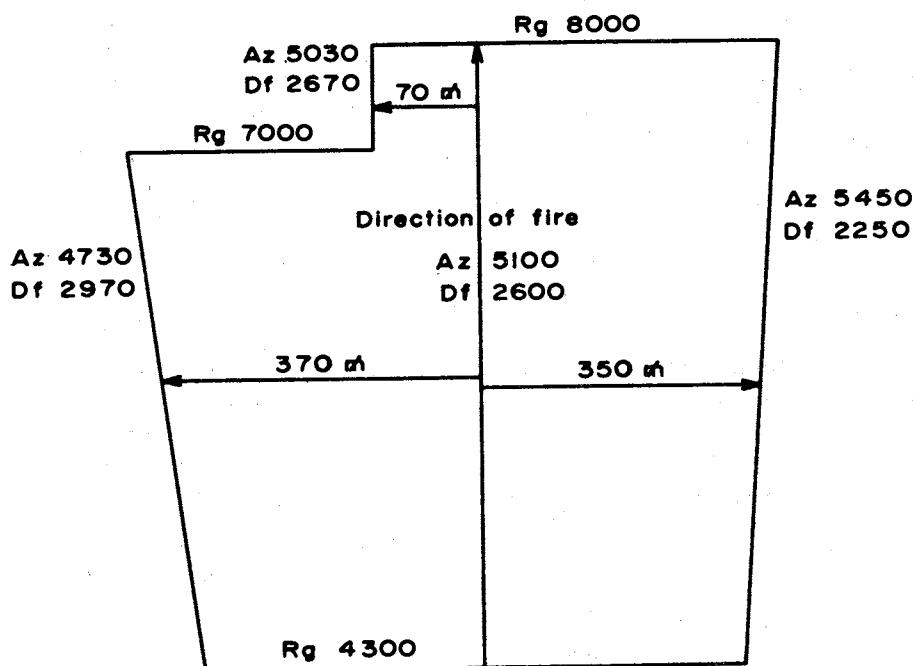


Figure 145. Basic safety diagram.

591. Minimum Fuze Setting (Low-Angle Fire)

The minimum fuze setting for time fuzes is the fuze setting corresponding to the elevation for minimum range plus the fuze correction (if known). The minimum fuze setting for VT fuzes is the time of flight corresponding to the elevation for minimum range plus 5.5 seconds. If the sum is not a whole number, the minimum safe time for VT fuzes is the next higher whole second.

592. Maximum Quadrant Elevation (Low-Angle Fire)

The maximum QE for each authorized charge is the sum of the following elements:

a. Site to the lowest point on the maximum range line.

b. Elevation for the maximum range. If corrections are known, they must be applied when the elevation is computed.

593. Deflection Limits

After registration, the deflection limits of the basic safety diagram must be corrected by adding the deflection correction to each deflection limit.

594. Sample Problem

a. *Prior to Registration.*

Given:

Safety card (para. 588b).

Basic safety diagram (fig. 145).

Altitude of battery, 390 meters.

Altitude of highest point, minimum range, 411 meters.

Altitude of lowest point, maximum range (right), 405 meters.

Altitude of lowest point, maximum range (left), 410 meters.

Find:

Minimum QE, minimum fuze setting (time), and maximum QE.

Solution:

Minimum QE

Altitude of highest point, minimum range	411 meters
Altitude of battery	390 meters
Vertical interval	+21 meters
Site (+21/4,300 GST)	+5 mils
Elevation (charge 5 GFT)	200 mils
Minimum QE	205 mils

Solution—Continued

Minimum Fuze Setting, Fuze M520

Fuze setting corresponding to minimum elevation	14.1 seconds
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Minimum Fuze Setting, Fuze M514

Time of flight corresponding to minimum elevation	13.7 seconds
	+5.5 seconds
	19.2 seconds

Minimum fuze setting for fuze M514 20.0 seconds

Maximum QE, right segment

Lowest altitude, maximum range	405 meters
Altitude of battery	390 meters
Vertical interval	+15 meters
Site (+15/8,000 GST)	+2 mils
Elevation (charge 5 GFT)	462 mils
Maximum QE	464 mils

Maximum QE (left segment)

Lowest altitude, maximum range	410 meters
Altitude of battery	390 meters
Vertical interval	+20 meters
Site (+20/7,000 GST)	+3 mils
Elevation (charge 5 GFT)	376 mils
Maximum QE	379 mils

b. *After Registration.*

Given:

GFT setting; GFT A: charge 5, lot XY, range 6,000, elevation 315, time 21.6.

Deflection correction, right 8 mils.

Find:

Minimum QE, minimum fuze setting, and maximum QE.

Solution:

Minimum QE

Site to highest point, minimum range	+5 mils
Elevation (GFT)	207 mils
Minimum QE	212 mils

Minimum Fuze Setting, M520

Fuze setting at minimum range (GFT)	14.6 seconds
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Minimum Fuze Setting, M514

Time of flight corresponding to elevation 207	14.2 seconds
	+5.5 seconds
	19.7 seconds
Minimum fuze setting for fuze M514	20.0 seconds

Maximum QE (right segment)

Site to lowest point maximum range	+2 mils
Elevation (GFT)	484 mils
Maximum QE	486 mils

Maximum QE (left segment)

Site to lowest point, maximum range	+3 mils
Elevation (GFT)	391 mils
Maximum QE	394 mils

Deflection Limits	Left	Intermediate	Right
Basic deflection limits	2,970	2,670	2,250
Deflection correction	R8	R8	R8
New deflection limits, mils	2,962	2,662	2,242

Note. Graphical equipment is used to determine elevations, site, and fuze settings for the fuze M520 when ranges permit their use; otherwise tabular equipment is used. Data is determined to the same accuracy as for firing.

595. Construction of Safety Diagram From Visible Reference Point

Occasionally, a safety card will specify a reference point instead of an azimuth and the lateral limits by angular measurements right and left of that reference point. The procedure for preparing the safety diagram is as follows:

a. Information from safety card:

Reference point blockhouse Signal Mountain.

Left limit: 350 mils left.

Right limit: 200 mils right.

b. After the pieces are laid and aiming posts are put out, determine the smallest angle between the line of fire, and the reference point by using the panoramic telescope of the base piece as an angle measuring instrument. (Assume that the battery has been laid, aiming posts have been placed at deflection 2,800, and an angle of 100 mils has been measured from the line of fire left to the reference point.)

Note. Since the panoramic telescope measures only clockwise angles, angles measured to the left of the line of fire are determined by subtracting the reading on the telescope sight from 3,200. In this example, measuring to the reference point would produce a reading of 3,100 (3,200 minus 3,100 equals 100 mils).

c. Using the LARS rule (left, add; right, subtract), determine the proper deflection to lay the pieces on the reference point (deflection 2,800, left 100, equals deflection 2,900).

d. Again using the LARS rule, apply the right and left angular measurements from the reference point specified on the safety card to the deflection required to lay on the reference point (fig. 146).

(1) Left limit: From deflection 2,900, left 350 equals deflection 50.

(2) Right limit: From deflection 2,900, right 200 equals deflection 2,700.

e. In case the reference point is not visible because of weather conditions, the azimuth to the reference point, if not given on the safety card, must be computed by using the coordinates of the reference point. The pieces may then be laid on that azimuth or any other convenient azimuth.

596. Special Situations

a. High-Angle Fire. When high-angle fire is employed, the safety limits are computed in the following manner:

(1) *Maximum quadrant elevation.* The maximum QE for minimum range is the sum of the elevation (to nearest mil) for minimum range and the site

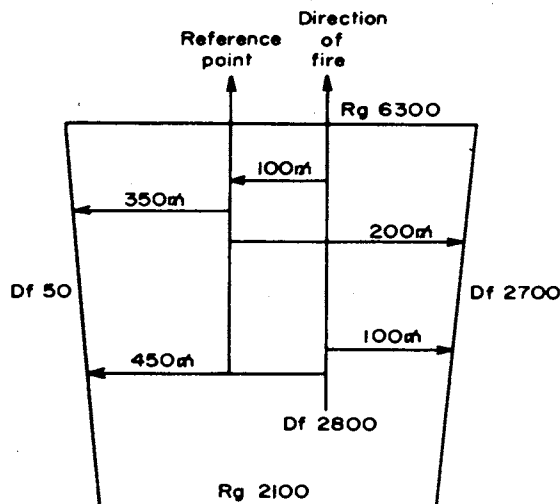


Figure 146. Safety diagram from visible reference point.

(to nearest mil) to the highest point on the minimum range line.

- (2) *Minimum quadrant elevation.* The minimum QE for *maximum* range is the sum of the elevation (to nearest mil) for maximum range plus the site (to nearest mil) to the lowest point on the maximum range line.
- (3) *Deflection limits.* When high-angle fire is employed, the deflection limits on the basic safety diagram are always modified to consider the drift. The right deflection limit is modified to the left by the amount of the *maximum* drift for the cannon. The left deflection limit is modified to the left by the amount of the *minimum* drift (high-angle) for the cannon. After a high-angle registration, the deflection limits are further modified by the amount of the deflection correction.

b. Illuminating Shell. When an illuminating shell is employed, the safety diagram is computed in the same manner as for shell HE in low-angle fire except that the illuminating tables of the tabular firing table for the appropriate weapon are used. In some areas, the range officer may determine a maximum QE for each charge to be fired.

c. Heavy and Very Heavy Artillery. Because of the great range and resulting large amount of drift in firing heavy artillery and very heavy artillery at long ranges, drift for low angle must be considered in computation of data for safety limits prior to registration or otherwise determining corrections. This is especially important when firing into small impact areas.

597. Safety Stakes

a. Safety stakes for each piece are an aid to the safety officer in checking lateral limits. The stakes are placed approximately 10 meters forward of each piece along the lateral limits specified on the safety card. By standing to the rear of a piece and glancing along the tube, the safety officer can easily see whether the tube is pointed close to the lateral safety limits. When the tube approaches the limits, the safety officer makes careful check on the deflection set on the piece and on the actual laying of the tube.

b. One method for placing safety stakes is as follows: Lay the tube in the direction in which the battery was initially laid. From the safety card, determine the angles (right and left) from this direction of fire to the right and left limits. Using the panoramic telescope, set off the angles from the direction of fire to the deflection limits and align the safety stakes with the vertical hairline.

Example: The basic safety diagram is that shown in figure 145. With the tube laid in azimuth 5,100, the sight is referred to deflection 2,830 (3,200 — 370), 3,130 (3,200 — 70), and 350 in order to set out the left, intermediate, and right safety stakes (fig. 147).

c. Another method of placing safety stakes is to traverse the tube to the lateral limits and sight through the tube to install the safety stakes.

d. For inclosed, self-propelled weapons, various aids to safety are used, since safety stakes cannot be seen from the piece. One method is to mark the deflection limits on the turret azimuth scale in chalk. The unit's SOP should indicate the approved method for the piece.

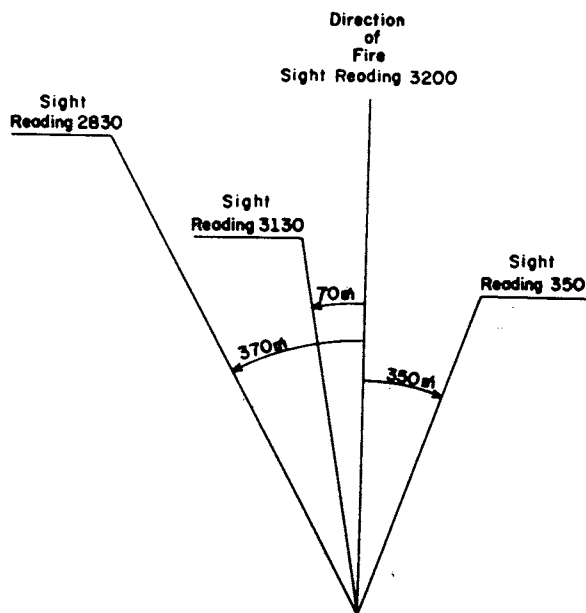


Figure 147. Safety Stake Diagram Based on Basic Safety Diagram.

APPENDIX I

REFERENCES

1. Publications Indexes

Department of the Army Pamphlets of the 310-series should be consulted frequently for latest changes or revisions of references given in this appendix and for new publications relating to material covered in this manual.

2. Army Regulations

AR 320-5	Dictionary of United States Army Terms.
AR 320-50	Authorized Abbreviations and Brevity Codes.
AR 385-63	Regulations for Firing Ammunition for Training, Target Practice, and Combat.
AR 700-1300-8	Malfunctions Involving Ammunition and Explosives.
AR 750-1000-8	Weapon Record Book for Other Than Small Arms.

3. Department of Army Pamphlets

DA Pam 108-1	Index of Army Motion Pictures, Film Strips, Slides, and Phono-Recordings.
DA Pam 310-series	Index of Military Publications.

4. Field Manuals

FM 3-5	Tactics and Techniques of Chemical, Biological, and Radiological Warfare.
FM 6-18	Mortar Battery, Airborne Division Battle Group.
FM 6-20-1	Field Artillery Tactics.
FM 6-20-2	Field Artillery Techniques.
FM 6-21	Division Artillery.
FM 6-50	4.2-inch Mortar M30.
FM 6-75	105-mm Howitzer M2 Series, Towed.
FM 6-76	105-mm Howitzer M4 on Motor Carriage M37.

FM 6-77

FM 6-81

FM 6-82

FM 6-87

FM 6-90

FM 6-92

FM 6-96

FM 6-115

FM 6-120

FM 6-122

FM 6-125

FM 6-140

FM 6-160

FM 11-40

FM 17-12

FM 17-78

FM 17-79

FM 17-80

FM 21-5

FM 21-6

FM 21-26

FM 21-30

FM 23-92

FM 100-5

105-mm Howitzer M52, Self-Propelled.

155-mm Howitzer M1, Towed.

155-mm Howitzer on Motor Carriage M41.

155-mm Gun M2 on Motor Carriage M40 and 8-inch Howitzer M2 on Motor Carriage M43.

155-mm Gun M2, 8-inch Howitzer M2, Towed.

155-mm Howitzer M44, Self-Propelled.

280-mm Gun T131 on Carriage T72.

The Field Artillery Searchlight Battery.

The Field Artillery Observation Battalion and Batteries.

Artillery Sound Ranging and Flash Ranging.

Qualification Tests for Specialists, Field Artillery.

The Field Artillery Battery.

Radar Set AN/MPQ-10.

Signal Corps Pictorial Operations.

Tank Gunnery.

Tank, 90-mm Gun M47.

Tank, 90-mm Gun, M48.

Tanks, 76-mm Gun, M41 and M41A1.

Military Training.

Techniques of Military Instruction.

Map Reading.

Military Symbols.

4.2-inch Mortar M2.

Field Service Regulations; Operations.

5. Technical Manuals

TM 5-230	General Drafting.	TM 9-1900	Ammunition, General.
TM 5-236-60	The American Ephemeris and Nautical Almanac for the Year 1960.	TM 9-1901	Artillery Ammunition.
		TM 9-1907	Ballistic Data, Performance of Ammunition.
TM 6-200	Artillery Survey.	TM 9-1950	Rockets.
TM 6-230	Logarithmic and Mathematical Tables.	TM 9-2008	Operation and Organizational Maintenance:
TM 6-240	Rule, Slide, Military, Field Artillery, with Case, 10-inch.		4.2-inch Mortar M30 and 4.2-inch Mortar Mounts M24 and M24-A1.
TM 9-319	75-mm Pack Howitzer M1A1 and Carriage M8.	TM 9-2009	4.2-inch Mortar M30 (T104) and 4.2-inch Mortar Mount M24 (T61).
TM 9-324	105-mm Howitzer M4, Mounted in Combat Vehicles.	TM 9-3004	8-inch Howitzer M2, Carriage M1, and Heavy Carriage Limber M5.
TM 9-325	105-mm Howitzer M2A1, Carriages M2A1 and M2A2, and Combat Vehicle Mount M4 and M4A1.	TM 9-3007	105-mm Howitzer M2A1, 105-mm Howitzer Recoil Mechanisms M2A1, M2A2, and M2A3, 105-mm Howitzer Carriages M2A1 and M2A2, and 105-mm Howitzer Mounts M4 and M4A1.
TM 9-331A	155-mm Howitzer M1 and 155-mm Howitzer Carriages M1A1 and M1A2.		280-mm Gun T131 and 280-mm Gun Carriage T72.
TM 9-331B	155-mm Howitzer M1 and Mount M14 (Mounted on 155-mm Howitzer Motor Carriage M41).	TM 9-3019	Operation and Organizational Maintenance:
TM 9-338-1	280-mm Gun T131 and 280-mm Gun Carriage T72.	TM 9-7004	Self-Propelled 155-mm Howitzer M44 (T194).
TM 9-524	12-inch Graphical Firing Tables.	TM 11-287	Radio Sets AN/VRQ-1, AN/VRQ-2, and AN/VRQ-3.
TM 9-525	Graphical Firing Tables M39, M40, M41, M42, M43, M44, M45, M46, M47, M48, M49, M50, and M51.	TM 30-245	Photographic Interpretation Handbook.
TM 9-575	Auxiliary Sighting and Fire Control Equipment.		
TM 9-717	105-mm Howitzer Motor Carriage M37.		
TM 9-747	155-mm Gun Motor Carriage M40 and 8-inch Howitzer Motor Carriage M43.		

6. Training Films

TF 6-1696	Fire Direction Procedure—Part I: Precision Fire.
TF 6-1697	Fire Direction Procedure—Part II: Area Fire.
TF 6-1703	Fire Direction Procedures—Part III: Observed Firing Chart.

7. Firing Tables

FT 4.2-F-1	Mortar, 4.2-inch, M30.	SNL C-20
FT 8-J-3	Firing Tables for Howitzer, 8-inch, M1.	
FT 40AA-A-3	Firing Tables; Gun, Automatic, 40-mm M1, and Gun, Dual, Automatic 40-mm, M2.	SNL C-21
FT 90AA-B-3	Firing Tables; Gun, 90-mm, AA, M1, M1A1, and M2.	SNL C-39
FT 105-H-5	Firing Tables; Howitzer, 105-mm, M2A1 and M4.	
FT 155-Q-3	Firing Tables; Howitzer, 155-mm, M1.	SNL C-63
FT 280-B-1	Gun, 280-mm T131, Firing Shell, HE, T122.	SNL C-86

8. DA Ordnance Supply Manuals

SM 9-5-1305	Ammunition; through 30 millimeter.	SNL D-29
SM 9-5-1310	Ammunition; over 30 millimeter up to 75 millimeter.	
SM 9-5-1315	Ammunition; 75 millimeter through 125 millimeter.	SNL D-49
SM 9-5-1320	Ammunition; over 125 millimeter.	SNL D-57
SM 9-5-1330	Grenades, Hand and Rifle, and Related Components.	SNL D-63
SM 9-5-1340	Ammunition; Rockets and Rocket Ammunition.	SNL G-232
SM 9-5-1345	Ammunition and Explosive Land Mines.	
SM 9-5-1375	Ammunition; Explosives, Bulk Propellants, and Explosive Devices.	SNL G-236
SM 9-5-1390	Ammunition; Fuzes and Primers.	SNL G-254
		SNL G-258

9. DA Ordnance Standard Nomenclature Lists

SNL A-85	Mortar, 4.2-inch, M30; Mount, Mortar, 4.2-inch, M24 and M24A1.	SNL G-259
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Howitzer, Pack, 75-mm, M1A1; Carriage, Howitzer (Pack), 75-mm, M8.

Howitzer, 105-mm, M2-A1, Carriage, Howitzer, 105-mm, M2A1 and M2A2; Mount, Howitzer, 105-mm, M4 and M4A1.

Howitzer, 155-mm M1; Carriage, Howitzer, 155-mm, M1A1 and M1A2; Mount, Howitzer, 155-mm, M14.

Howitzer, 105-mm, M4; Mount, Gun, Combination, M52 and M71.

Howitzer, 105-mm, T96-E1; Mount, Howitzer, 105-mm, T67E1.

Howitzer, 8-inch, M2; Carriage, Howitzer, 8-inch, M1; Limber, Carriage, Heavy, M5.

Howitzer, 8-inch, T89; Gun, 155-mm, T80; Mount, 155-mm Gun and 8-inch Howitzer, T58.

Gun, 280-mm; T131; Carriage, Gun, 280-mm, T72.

Howitzer, 155-mm, M45 (T186E1).

Carriage, Motor, 155-mm Gun, M40; Carriage, Motor, 8-inch Howitzer, M43.

Carriage, Motor, 155-mm Howitzer, M41.

Tank, 90-mm Gun, M48 and M48A1.

Howitzer, 105-mm, Self-Propelled, T98E1.

Gun, Self-Propelled, Full Tracked, 155-mm, T97 and Howitzer, 8-inch, Self-Propelled, Full Tracked, 8-inch T108.

SNL G-262	Tank, 90-mm Gun, M47.	DA Form 6-14	Firing Battery Data Sheet.
SNL G-279	Howitzer, Self-Propelled, Full Tracked, 155-mm, M44 (T194).	DA Form 6-15	Met Data Correction Sheet.
SNL R-1	Ammunition, Fixed and Semifixed, Including Subcaliber, for Pack, Light and Medium Field, Aircraft, Tank, and Antitank Artillery, Including Complete Round Data.	DA Form 6-16 DA Form 6-16-1	FDC Computer's Record. FDC Computer's Record for 4.2-inch Mortar.
SNL R-4	Ammunition, Mortar, Including Fuzes, Propelling Charges, and Other Components.	DA Form 6-17	Firing Battery Recorder's Sheet.
SNL S-9	Rocket, All Types and Components.	DA Form 6-51 DA Form 6-52	Data Correction Sheet. Correction Sheet, 280-mm Gun.
		DA Form 6-53	Target Grid Scale 1: 25,000 meters.
		DA Form 6-54	K-Transfer Technique.
		DA Form 6-55	High-Burst (Center of Impact) Registration.

10. DA Forms

DA Form 6-12	Record of Precision Fire.
DA Form 6-12-1	Record of Precision Fire for 4.2-inch Mortar.
DA Form 6-13	Firing Battery Section Data Sheet.

11. Joint Army Navy Air Force Procedure

JANAP 164	Joint Radio and Telephone Procedure for Conduct of Artillery and Naval Gunfire.
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APPENDIX II

8-INCH HOWITZER NUCLEAR DELIVERY TECHNIQUES

Section I. INTRODUCTION

1. General

a. Procedure. This appendix describes the fire direction technique for delivery of the 8-inch howitzer nuclear round. Nuclear delivery techniques for the 8-inch howitzer are identical to standard gunnery procedures with the exception of the determination of the fuze setting, the averaging of velocity errors (VE), and the addition of the ballistic corrections for the nuclear round.

b. Nomenclature.

- (1) The high explosive spotting round (HES M424) is used for registrations and adjustments.
- (2) The nuclear round (NUC M422) is used for fire for effect.

c. Preferred Techniques. The two preferred techniques for the delivery of nuclear rounds from an 8-inch howitzer are—

- (1) Met plus VE.
- (2) K-transfer (GFT).

d. Fire-for-Effect Technique. If the information necessary for the employment of a preferred technique is not available, and adjustment and fire-for-effect ("will adjust") technique may be used.

2. Requirements for Delivery Techniques

Requirements for the various delivery techniques of 8-inch nuclear rounds are as follows:

a. Met Plus VE.

- (1) Accurate survey data for the gun and target.
- (2) Registration data for shell HES.
 - (a) Valid VE.
 - (b) Valid deflection correction.
 - (c) Valid fuze correction.
- (3) Current met data.

b. K-Transfer (GFT).

- (1) Accurate survey data for the gun and target.
- (2) Target area base established on common control.

c. Will Adjust.

- (1) Weapon within range.
- (2) Observer in position to observe.

3. Accuracy

All data are determined to the same accuracy as standard gunnery procedures.

4. Selection of Delivery Technique

a. Considerations in Selection of Delivery Technique. Listed below are some of the considerations in the selection of delivery technique. The S3 must evaluate all considerations and then use sound judgment in making his decision.

- (1) Tactical situation.
- (2) Commander's guidance.
- (3) Desirability of surprise.
- (4) Weather conditions.
- (5) Availability of spotting shells.
- (6) Time available.
- (7) Registration restrictions.
- (8) Survey.
- (9) Validity of current registration and VE data.

b. Registrations. In a nuclear war, it is anticipated that the unit will register (three-round high burst) at least one weapon with shell HES immediately after occupation of position. This registration will establish a VE (to be averaged) for the met plus VE technique and a GFT setting for the K-transfer method. After this registration, the S3 will have three options for delivery of fire on a target. The selection of the technique is based on the considerations listed in *a* above.

- (1) Met plus VE.
- (2) K-transfer.
 - (a) Use registration data if still current.
 - (b) Reregister if data is not current.
 - (c) Use GFT setting updated with current met message plus VE.
- (3) Will adjust.

c. Accuracy of Techniques. The accuracy of each technique is dependent on some of the same considerations listed in *a* and *b* above. There are so many variables that one technique cannot be considered as the most accurate technique under all conditions. General guides are as follows:

- (1) The met plus VE technique will probably be the most accurate method under most conditions. This is particularly true when the target is on fringe areas of the transfer limits, the target is outside the transfer limits, or the registration data are not current. The accuracy of this technique is primarily dependent on the validity of the met messages.
- (2) The K-transfer method using current registration data will yield an accurate solution. If the target is in close proximity to the high-burst registration, the accuracy should equal, or possibly exceed that of the met plus VE technique. On the fringe areas of the transfer limits or outside the transfer limits, the accuracy can be expected to decrease. The principal disadvantage of this system is that a registration will usually have to be fired to develop current data.
- (3) The will-adjust technique is the least desirable method for several reasons. The accuracy of this technique is dependent on the ability of the observer, the probable errors at the target, and the size of the observer's bracket. This technique will only be used when the other techniques cannot be used. The disadvantages are the time consumed, loss of surprise, requirement for an observer in position, inaccuracy of fire (normally 100-meter bracket split plus the probable error), and number of rounds (HES) used in adjustment.

d. Time Requirements. The time required to prepare fire commands to fire a nuclear round is dependent on data available. If a current GFT setting is available, the K-transfer technique will be the fastest. The next most rapid solution is met plus VE. The K-transfer technique will be the slowest if a registration must be fired, due to the time required to register. The will-adjust

technique will be dependent on the speed of adjustment.

e. Ballistic Corrections. Except for the ballistic correction table (table L), the 8-inch howitzer firing tables used for nuclear delivery are constructed for projectile HES (M424). Because of ballistic differences, a spotting round (HES M424) and a nuclear round (NUC M422) fired with the same data will not burst at the same point. When the nuclear projectile is to be used, the quadrant elevation and fuze setting for the projectile HES must be corrected by the amount of ballistic corrections determined from the firing table. The firing tables are entered with the final quadrant elevation (QE) for projectile HES rounded to the nearest listed value in the table and the height of burst above gun to the nearest 1 meter. Corrections to QE are determined to the nearest 1 mil, and to fuze setting to the nearest 0.1. These values can usually be visually interpolated.

f. Determination of Fuze Correction.

- (1) The large vertical intervals involved in the delivery of nuclear rounds necessitate the consideration of the complementary angle of site (complementary range) in the determination of the fuze correction. A larger fuze setting is required to deliver a projectile to a point at a given range plus a 200-meter vertical interval than to a point at the same range at the same altitude. This difference in fuze setting is in direct relationship to the complementary angle of site (complementary range). This is true in conventional high explosive (HE) delivery for all weapons. However, in firing conventional HE, the vertical intervals and comp sites are normally small; consequently, there is a negligible effect on the fuze setting. The procedure for determining the fuze correction graphically is as follows:
 - (a) Determine the angle of site and site (GST).
 - (b) Determine the comp site (site—angle of site).
 - (c) Determine the fuze setting for the adjusted elevation plus comp site (GFT).
 - (d) Subtract the fuze setting for the

adjusted elevation plus comp site from the fuze setting fired. The procedure for determining the fuze correction with the tabular firing table is the same, except that the elevation plus comp site is determined by adding the comp range to the chart range for the achieved high-burst (HB) location and interpolating for elevation plus comp site in table F.

- (2) The following illustrates the determination of the fuze correction with the GFT and GST (charge 1, projectile HES). Chart data to high-burst location.

Range	3,490 meters
Height of burst above gun	+162 meters
Adjusted data for the high-burst:	
QE	389 mils
Fuze setting	15.9
Fuze correction:	
Fuze setting fired	15.9
Site to HB (+162/3490; chg 1, TAG, GST)	+53 mils
Angle of site (+162/3490; C and D scales GST)	+47 mils
Comp site (+53—(+47))	+6 mils
Adjusted elevation (389—(+53))	336 mils
Adjusted elevation plus comp site (336+(+6))	342 mils
Fuze setting for adjusted elevation plus comp site (GFT)	16.5
Fuze correction (15.9—16.5)	—0.6

- (3) When this fuze correction is applied to a target, it must be added to the fuze setting for the elevation plus comp site to the target.

g. Velocity Error.

- (1) Velocity error (VE) includes deviations from standard for the weapon, ammunition, firing chart, met, and survey. Standard gunnery techniques require the VE to be averaged in a position and discarded after registration in a new position. The following factors in relation to VE for nuclear delivery must be considered:

- Nuclear delivery units will have a higher survey priority than other units.
- Registrations may be fired only once per position or less.
- Manufacturer's tolerances are less for the spotting and nuclear rounds than for conventional ammunition.

- (2) Accordingly, the VE is continually averaged at every opportunity rather than being discarded after registration in a new position. Judgment must be used in the continual averaging of these velocity errors. A large deviation of a new VE from the average VE should be viewed critically, and the error corrected or the reason for the error determined and isolated. If the reason cannot be determined, it is usually better to leave this VE out of the average.

Section II. MET PLUS VE

5. Met Plus VE

a. Determination of VE and Deflection Correction. The VE and deflection correction for shell HES are determined with the same procedure used for determining the VE and deflection correction for conventional shell HE described in chapter 20. The VE and deflection correction for nuclear delivery should be determined as soon as possible after occupation of position, they should not be delayed until the receipt of a nuclear mission.

b. Determination of the Fuze Correction. The fuze correction is determined as outlined in paragraph 4 of this appendix.

6. Sample Problem—Determination of Velocity Error, Deflection Correction, and Fuze Correction

a. Chart Data to Point Selected for High Burst.

Deflection	2,544 mils
Range	9,660 meters
Height above gun	+180 meters

b. Determination of Firing Data for High-Burst Registration (Charge 3, Shell HES).

(1) QE to be fired:

Elevation (range 9,660, GFT) --- 306 miles
 Site (+180/9,660; chg 3, TAG GST) --- +20 miles
 QE (306+20) --- 326 miles

(2) Fuze setting to be fired:

Angle of site (+180/9,660; C and D scales, GST) --- +19 miles
 Comp site (+20—(+19)) --- +1 mil
 Elevation plus comp site (306+ (+1)) --- 307 miles
 Fuze setting --- 27.3

(3) Deflection to be fired:

Chart deflection --- 2,544 miles

(4) These firing data may be determined from the tabular firing tables using the comp range table to determine the entry range. The entry range is used to determine the elevation plus comp site and the fuze setting. The angle of site is added to the elevation plus comp site to determine the QE.

c. Chart Data to the Achieved High-Burst Location (Graphic Solution or Computed).

Deflection --- 2,547 miles
 Range --- 9,520 meters
 Height of burst above gun --- +157 meters

d. Determination of the Total Range Correction.

QE fired --- 326 miles
 Site (+157/9520; chg 3, TAG, GST) --- +18 miles
 Adjusted elevation (326—(+18)) --- 308 miles
 Range for elevation 308 (GFT) --- 9,700 meters
 Total range correction (9700—9520) --- +180 meters

Note. The total range correction can be determined, using the tabular firing table, by subtracting the range corresponding to the elevation plus comp site (QE minus angle of site) from the entry range (chart range plus comp range) to the achieved high burst.

e. Determination of Fuze Correction.

Fuze setting fired --- 27.3
 Fuze setting corresponding to adjusted elevation plus comp site (309; GFT) --- 27.4
 Fuze correction --- -0.1

f. Determination of Deflection Correction.

Deflection fired --- 2,544 miles
 Deflection to chart location of HB --- 2,547 miles
 HB registration deflection correction (2544-2547) --- Right 3 miles
 Met deflection correction (fig. 148) --- Right 3 miles

g. Determination of Met Range Correction and Met Deflection Correction (fig. 148).

- (1) Battery laid on Az 2000, Df 2600.
 (2) Azimuth fired --- 2,056 miles

(3) Weight of projectile --- 240 pounds
 (4) Altitude of gun --- 326 meters
 (5) Altitude of burst --- 483 meters
 (6) Propellant temperature --- 66° F.
 (7) Latitude of gun --- 34° N.
 (8) Concurrent NATO met message:
 METS 39 MIFMIF
 071014 049982
 USL
 002618 009976
 012618 009978
 022720 009978
 032927 004981
 042927 002982
 053129 004987

h. Determination of VE (fig. 148).

VE (fig. 148) --- -5 feet per second

i. Results.

VE (fig. 148) --- -5 feet per second
 Fuze correction --- -0.1
 Deflection correction --- Right 3 miles
 Met deflection correction --- Right 3 miles

7. Application of Met Plus VE

a. The application of met plus VE and deflection correction are the same as for shell HE (ch. 20) except for the fuze correction and the ballistic corrections. When the met plus VE technique is used, the data will be computed to the target. The GFT setting will be kept current by the use of met plus VE for emergencies when there is not sufficient time to compute a met plus VE to the target.

b. The fuze correction must be applied to the elevation plus comp site for the target.

c. The ballistic corrections are determined as indicated in paragraph 4, this appendix.

8. Sample Problem—Application of Met Plus VE

This problem is a continuation of the problem in paragraph 6.

a. Chart Data to Target.

Range --- 10,520 meters
 Desired height of burst above gun --- +150 meters
 Deflection --- 2,648 miles

b. Solution of met message for met range correction and met deflection correction (fig. 149).

(1) Weight of projectile --- 244 pounds
 (2) Propellant temperature --- 71° F.
 (3) Altitude of battery --- 326 meters
 (4) Altitude of target --- 336 meters
 (5) HB above target --- +140 meters
 (6) Chart deflection to target --- 2,648 miles
 (7) Battery laid on azimuth --- 2,000 miles

MET DATA CORRECTION SHEET														
(FM 6-40)														
BATTERY DATA					MET MESSAGE									
Charge	3	Adj OE	326	Chart Rg	9520	Latitude	30°N	Type Msg	3	Octant	9	Area/Unit	MIF MIF	
Alt of Btry (10m)		330			Date	07	Time	10-14	Alt MDP		049	Pressure	98.2	
Alt of MDP		490			Line Nr	03	Wind Dir	29	Wind Speed	27	Air Temp	100.4	Air Density	98.1
Btry ^{above} below MDP (Δh)		-160			Δh Corrections			⊕ - 0.3		⊕ - 1.6				
Alt of Target (nearest meter)					Corrected Values			100.7		99.7				
Height of burst above target														
Alt of burst		483												
Alt of Btry (nearest meter)		326												
Height of Target (burst) above gun (m)		+157			Comp Rg	+22		Chart Rg	9520		Entry Rg	9542		
WIND COMPONENTS AND DEFLECTION														
When direction of wind is less than direction fire add		6400												
Dir of Wind		2900												
Dir of fire (2056)		2100												
Chart Dir of Wind		800												
Cross Wind	Wind Speed	27	x Comp	L 71	= L 19	Knots	x	47	=	Cross Wind Corr	L 8.9			
Range Wind	Wind Speed	27	x Comp	T 71	= Tail (Head) 19	Knots				Met Defl Corr	L 88.4 or			
MET RANGE CORRECTIONS 3														
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus								
Range Wind	T 19	0	T 19	+9.1	172.9									
Air Temp	100.7	100%	D 0.7	-5.4		3.8								
Air Density	99.7	100%	D 0.3	-33.5		10.0								
Proj Weight	240	242	I 2	-1		2.0								
Rotation	-33 x .87						28.7							
						172.9	44.5							
						44.5								
					Met Rg Corr	128.4								
COMPUTATION OF VE														
VE		-5 f/s		D +6.7	Total Range Corrections	+180								
Prop Temp	66 °F	Correction to MV for Prop Temp	-3 f/s	I -6.5	Met Range Correction	+128								
ΔV		-8 f/s		MV unit Corr +6.7	ΔV Range Correction	+ 52								
					Total Range Correction									
Old VE _____ + New VE _____ ÷ 2 = Ave VE _____ f/s														
Concentration #				Battery				Date/Time						

Figure 148. Met data correction.

MET DATA CORRECTION SHEET (FM 6-60)									
BATTERY DATA					MET MESSAGE				
Charge	Adj OE	Chart Rg	Latitude	Type Msg	Octant	Area/Unit			
3		10,520	300N	3	9	MIFMTF			
Alt of Btry (10 ft)		330		Date	Time	Alt MDP		Pressure	
				07	14-18	049		98.0	
Alt of MDP		490		Line Nr	Wind Dir	Wind Speed	Air Temp	Air Density	
				04	30	25	100.8	97.3	
Btry above MDP (Δh)		-160		Δh Corrections			⊕ - 0.3	⊕ - 1.6	
Alt of Target (nearest meter)		336		Corrected Values			101.1	98.9	
Height of burst above target		+140							
Alt of burst		476							
Alt of Btry (nearest meter)		326							
Height of Target (burst) above gun (m)		+150		Comp Rg	+24	Chart Rg	10,520	Entry Rg	10,544
WIND COMPONENTS AND DEFLECTION									
When direction of wind is less than direction fire add		6400							
Dir of Wind		3000							
Dir of fire (1952)		2000							
Chart Dir of Wind		1000							
Cross Wind	Wind Speed	25	Comp	⊕ .83	⊖ .21	Knots	⊖ .52	Cross Wind Corr	⊖ 10.9
Range Wind	Wind Speed	25	Comp	⊕ .56	⊖ .14	Knots	⊖ .30	Met Defl Corr	⊖ 4.3 or 4
MET RANGE CORRECTIONS									
	Known Values	Standard Values	Variations from Standard	Unit Corrections	Plus	Minus			
Range Wind	⊕ 14	0	⊕ 14	+11.3	158.2				
Air Temp	101.1	100%	⊕ 1.1	-8.4		9.2			
Air Density	98.9	100%	⊕ 1.1	-37.9		41.7			
Proj Weight	244	242	⊕ 2	+2	4.0				
Rotation	-35 x .87						30.4		
						162.2	81.3		
						81.3			
						Met Rg Corr	80.9		
COMPUTATION OF VE									
Prop Temp	71 °F	VE	-5 1/s	D = +7.0	Total Range Corrections				
		Correction to MV for Prop Temp	+1 1/s	I = -6.8	Met Range Correction	+81			
		ΔV	-4 1/s	MV unit Corr	+7.0	ΔV Range Correction	+28		
						Total Range Correction	+109		
Old VE _____ + New VE _____ ÷ 2 = Ave VE _____ 1/s									
Concentration #			Battery			Date/Time			

Figure 149. Met data correction.

(8) Aiming posts at deflection	2,600 mils
(9) VE	-5 feet per second
(10) Charge	3
(11) Current NATO met message:	
METS39	MIFMIF
071418	049980
USL	
003011	011970
013014	011971
023120	009971
033222	009973
043025	008973
053029	008972

c. Application of VE to determine total range corrections is shown in figure 149.

d. *Determination of QE.*

Total range correction	+109 meters
Chart range	10,520 meters
Corrected range (10,520 + (+109) 10,629 or 10,630)	10,630 meters
Elevation (10,630, GFT)	360 mils
Site (+150/10,520; ch 3, TAG, GST)	+16 mils
QE for spotting round	376 mils
QE correction for the ballistic difference.	
(Enter the ballistic correction table, Table L in tabular firing table, with the nearest listed QE and the height of burst above gun to the nearest meter.)	
	+10 mils
QE to be fired	386 mils

Note. The QE may be determined from the tabular firing table by obtaining the elevation plus comp site

from the total range correction plus the entry range (chart range plus comp range) to the target and adding the angle of site. The ballistic correction must still be added to this QE.

e. *Determination of the Fuze Setting.*

Angle of site (+150/10,520; chg 3, C and D scales, GST)	+15 mils
Comp site (+16—(+15))	+1 mil
Elevation plus comp site (360 + (+1))	361 mils
Fuze setting for elevation 361 mils (GFT)	31.2
Fuze correction from registration	-0.1
Fuze setting for the spotting round	31.1
Fuze correction for the ballistic difference (Enter ballistic correction table, Table L in the tabular firing table, with the nearest listed QE and HB above gun to the nearest meter.)	+0.5
Fuze setting to be fired	31.6

Note. The fuze setting may be determined from the tabular firing table by using the elevation plus comp site discussed in d above, and adding the fuze corrections for registration and for ballistic difference.

f. *Determination of Deflection.*

Chart deflection	2,648 mils
Deflection correction	Right 3 mils
Change in the weather from the met at registration to the current met (R3 to R4)	Right 1 mil
Deflection to be fired	2,644 mils

g. *Firing Data.*

Deflection	2,644 mils
Fuze setting	31.6
QE	386 mils

Section III. K-TRANSFER

9. K-Transfer GFT Method

a. *General.* The K-transfer technique may be solved with either graphical equipment or tabular firing tables. Both solutions have the same accuracy; consequently, the graphical solution will normally be used. The K-transfer GFT technique utilizes a GFT setting a fuze correction, and a deflection correction. Corrections are determined from a HB registration with three rounds of HES shell. The ballistic difference between the spotting rounds and the nuclear round must be applied in the same manner as in the met plus VE technique. The differences, if any, between the projectile weights and propellant temperatures of the spotting round and the nuclear round must also be applied.

b. *Determination of GFT Setting.* GFT setting is determined in the same manner as HE ammunition except that the fuze correction, as discussed in paragraph 4f, this appendix, replaces the time gage line.

c. *Determination of Fuze Correction.* Fuze correction is determined using the elevation plus comp site method as discussed in paragraph 4f, this appendix.

d. *Determination of Deflection Correction.* Deflection correction is determined in the normal manner by going from chart deflection to adjusted deflection and establishing a deflection correction scale. The transfer limits are the same as for conventional HE ammunition.

e. *Application of Data to a Target.* The GFT setting is used in the conventional manner to determine the elevation. The GST is used to

determine the site and the angle of site. The fuze setting is determined from the elevation plus comp site plus the registration fuze correction. The QE and fuze setting are corrected for the ballistic differences as indicated in paragraph 4e, this appendix. The deflection correction is determined from the deflection correction scale.

10. Sample Problem—Determination of GFT Setting, Fuze Correction, and Deflection Correction

a. Known Data.

Shell.....	HES
Lot.....	XY
Charge.....	3
Weight of projectile.....	241 pounds
Propellant temperature.....	66° F.
Altitude of battery.....	318 meters

b. Fired (Adjusted) Data for High-Burst Registration.

Deflection.....	2639 mils
Fuze setting.....	26.7
QE.....	325 mils

c. Chart Data to High-Burst Location.

Deflection.....	2,635 mils
Range.....	9,370 meters
Height of burst above gun.....	+184 meters

d. Determination of GFT Setting.

Site (+184/9370; chg 3, TAG, GST)	+21 mils
Elevation (325—(+21))	304 mils
GFT: Chg 3, lot XY, rg 9370, el 304.	

e. Determination of Fuze Correction.

Angle of site (+184/9370; C and D scale, GST)	+20 mils
Comp site (+21—(+20))	+1 mil
Elevation plus comp site (304+(+1))	305 mils
Fuze setting for elevation plus comp site (GFT)	27.1
Fuze correction (26.7—27.1)	—0.4

f. Determination of Deflection Correction.

Adjusted deflection	2,639 mils
Chart deflection	2,635 mils
Registration deflection corrections (center of the deflection correction scale)	Left 4 mils

g. Results.

GFT: Chg 3, lot XY, rg 9370, el 304.	
Fuze correction	—0.4
Deflection correction	Left 4 mils

11. Sample Problem—Application of GFT K-Transfer Technique

This problem is a continuation of the problem in paragraph 10. Projectile weight (shell nuclear), 240 pounds; current propellant temperature, 74° F.

a. Chart Data to Target.

Range.....	10,470 meters
Deflection.....	2,532 mils
Altitude of target.....	341 meters
Desired height of burst above target	+150 meters

b. *Determination of Entry Range.* (Entry range is necessary for determination of unit corrections for projectile weight and propellant temperature in c below. Visual interpolation usually is possible because entry range is used to the nearest 100 meters.)

Complementary range (enter table at chart range and height of burst above gun) —	+28 meters
Chart range.....	10,470 meters
Entry range.....	10,498 meters

c. *Determination of Corrections for Difference in Projectile Weight and Propellant Temperature.*

(1) Correction for projectile weight:

Weight of projectile (nuclear)	240 pounds
Weight of projectile used for registration	241 pounds
Variation from registration value	Decrease 1 pound
Unit correction determined at entry range (10,500)	0 meters
Correction	0 meters

(2) Correction for propellant temperature.

Correction to muzzle velocity for current propellant temperature (74° F.)	+3 feet per second
Correction to muzzle velocity for propellant temperature at registration (66° F.)	—3 feet per second
Variation from registration value	Increase 6 feet per second
Unit correction (Determined at entry range)	—6.8 meters
Correction	—41 meters

d. Determination of QE:

Range plus projectile weight and propellant temperature differences (10,470+(0)+(—41)) = 10,429 or 10,430	10,430 meters
Elevation (use GFT with GFT setting)	365 mils
Site (+173/10,470; chg 3, TAG, GST)	+19 mils

QE shell HES (365+(+19))	384 mils
QE ballistic correction (ballistic correction table in tabular firing table, use QE to nearest listed value and HB to the nearest meter)	+10 mils
QE to be fired	394 mils
<i>e. Determination of Fuze Setting.</i>	
Angle of site (+173/10,470; C and D scales, GST)	+17 mils
Comp site (+19-(+17))	+2 mils
Elevation plus comp site (365+(+2))	367 mils
Fuze setting for elevation plus comp site (367)	31.6
Registration fuze correction	-0.4
Ballistic fuze correction (ballistic correction table in tabular firing table, use nearest listed QE and the HB to the nearest 1 meter)	+0.5
Fuze setting to be fired	31.7
<i>f. Determination of Deflection to be Fired.</i>	
Chart deflection	2,532 mils
Deflection correction (deflection correction scale)	L 5 mils
Deflection to be fired	2,537 mils
<i>g. Firing Data.</i>	
Concentration	N101

Shell	Nuclear
Lot	WY
Charge	3
Deflection	2,537 mils
Fuze setting	31.7
QE	394 mils

12. K-Transfer Method Using Tabular Firing Table

The solution using the tabular firing table is performed in the same manner as the graphical solution except that range K and entry range must be used.

13. Sample Problem—Determination and Application of Range K, Fuze Correction, and Deflection Correction

This is the same problem illustrated in paragraphs 10 and 11. The solution is shown on the K transfer form (fig. 150). (This form will not become a standard DA form because the K-transfer technique will normally be accomplished using the graphical firing tables and graphical site tables.)

Section IV. WILL-ADJUST TECHNIQUE

14. Will-Adjust Procedure

a. General. If the information necessary to employ the met plus VE technique or the K-transfer technique is not available and a nuclear round must be delivered, an adjustment may be made with shell HES followed by fire for effect with shell NUC. The procedure during adjustment is the same procedure used for a will-adjust mission for conventional shell HE. The observer adjusts the height of burst to the normal 20 meters. The deflection, elevation, site, 100/R, and fuze setting are determined in exactly the same manner as for shell HE. The fuze setting is not determined using the elevation plus comp site method during the adjustment phase, because the vertical interval (VI) normally will be small and the observer will automatically correct for the small errors during the adjustment.

b. Fire-for-Effect Data.

- (1) The chart data is determined in the same manner as the adjustment phase. The observer's fire-for-effect request should place the burst over the target with a height of burst of 20 meters.

The height above the target must be corrected by the difference between the height of the last round in the adjustment and the desired height above target for the nuclear round (fig. 150.1). If the observer requested L20, U5, +50, FFE and the desired height of burst above target for the nuclear round is +180, a height of burst correction of U165 must be applied. Since the observer requested U5 and he is striving for a 20-meter height-of-burst, then the last round must have been 15 meters ($20 - 5 = 15$) above the target. Subtracting the 15 meters already achieved from the desired 180 meters results in a height-of-burst correction of U165 meters. If the observer requests L20, +50, FFE and the desired height above target is +180 meters, the correction would be U160. Since the observer did not make a height-of-burst correction, the height of burst is correct (20 meters). A correction of U160 would be applied ($180 - 20 = 160$).

Figure 150. K-Transfer Technique—Rescinded.

- (2) The large height-of-burst correction requires the consideration of site (angle of site + comp site) instead of the 100/R value which is only angle of site. Additionally; the fuze setting must be corrected by the amount of comp site involved. This requires the GST computation of both site and angle of site, using the height-of-burst correction and the fire-for-effect range. The site is included as the height-of-burst correction to the last site fired. The comp site is determined (site—angle of site) and added to the elevation for the fire-for-effect range to determine the fuze setting. A range correction for a difference in projectile weight and propellant temperature must be applied, if appropriate, before elevation and fuze setting are determined.
- (3) The QE for the spotting round is the elevation (corresponding to the chart range plus the range correction for propellant temperature (PT) and projectile weight (PW), plus the site for the additional height above target, plus the last site fired.
- (4) Ballistic corrections to QE and fuze setting are determined at the QE for the spotting round and the total height of burst above gun (sum of the initial vertical interval, the net observer's height-of-burst corrections, and the desired height of burst above the target (fig. 150.1)).
- (5) The QE to be fired is the QE for the spotting round in (3) above, plus the ballistic QE correction.
- (6) The fire-for-effect deflection is the chart deflection to the final target needle location.
- (7) The time to be fired is the fuze setting corresponding to the elevation plus comp site, plus the fuze correction (if any), plus the ballistic correction (determined as in (4) above).

15. Sample Problem Will-Adjust Procedure

a. Chart Data to Initial Location Requested by Observer (fig. 150.2):

Range -----	3,460 meters
Deflection -----	2,689 mils
Altitude of the battery -----	318 meters
Map altitude of the target -----	336 meters
Desired height of burst above target -----	+180 meters
Projectile weight (HES and NUC) -----	242 pounds
Propellant temperature (HES and NUC) -----	70° F.

b. Determination of Initial Data Using Charge 1 (fig. 150.2).

c. Determination of Subsequent Data (fig. 150.2).

d. Determination of Fire-for-Effect Data (fig. 150.2).

(1) Determination of QE.

Height of burst in relation to the target and the last round fired (20 —5) -----	+15 meters
Desired height of burst above target -----	+180 meters
Height of burst correction (180 —15) -----	+165 meters
Site correction (+165/3500; chg 1, TAG, GST) -----	+54 mils
Entry range (3500+(+52)) (Not required because PT and PW corrections are not necessary in this problem) -----	3,552 meters
Elevation for range 3500 (GFT) -----	319 mils
Site (last site fired (+9) + site correction (+54)) -----	+63 mils
QE for spotting round -----	382 mils
Total target height above gun (desired HB above target (+180) + vertical interval (+18) + net observer corrections (—5)) -----	+193 meters
QE ballistic correction (+193 HB and 380 QE) -----	+10 mils
QE to fire nuclear round -----	392 mils

(2) Determination of fuze setting.

Angle of site for HB correction (+165/3500 C and D scales GST) -----	+48 mils
Comp site (+54—(+48)) -----	+6 mils
Elevation +comp site (319+6) -----	325 mils
Fuze setting for elevation 325 -----	15.7
Ballistic fuze correction (+193	

HB and 380 QE) (Fig. 150.1) +.3
 Fuze setting to fire ----- 16.0
 (3) *Determination of deflection.*
 Deflection (chart deflection to
 FFE location) ----- 2,697 mils

(4) *Fire for effect data.*

Deflection ----- 2,697 mils
 Fuze setting ----- 16.0
 QE ----- 392 mils

BALLISTIC AND HEIGHT OF BURST CORRECTIONS

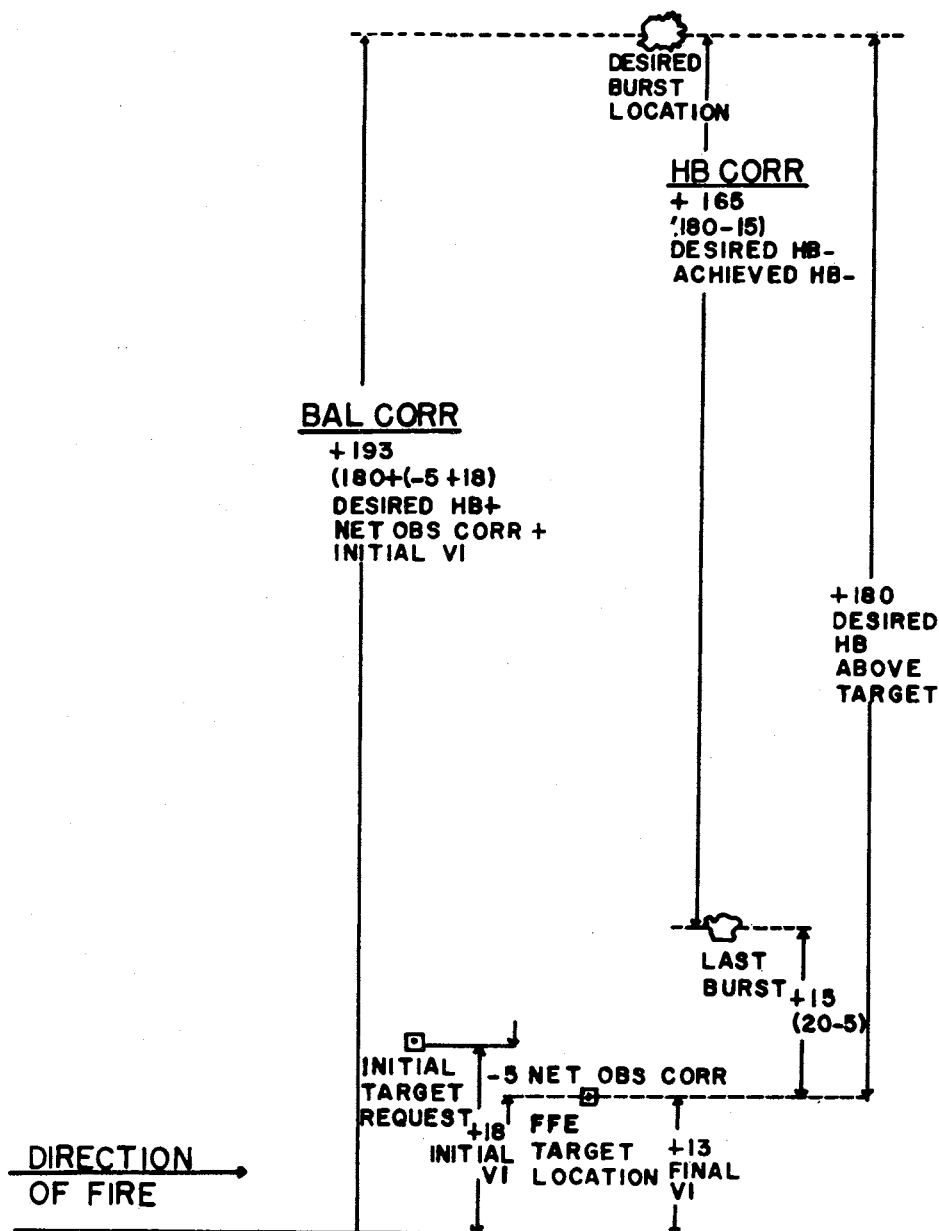


Figure 150.1. Ballistic and height of burst correction.

FDC COMPUTER'S RECORD (FM 6-40)													
Battery B		Time mission Received 1420 Completed 1450				Date 31 MAR 64		Concentration number N 101					
Fire mission 31 , COORD. 41863795, AZ 4170, INF BN ASSEMBLY AREA, WA						Correction 0 Deflection 2689 Range 3460 EL 314 Site (+18/3460, 6ST) = +6 20/R = +6 326 100/R 29		INITIAL FIRE COMMANDS # 1 Adjust, Sp Instr Sh HES Lot XY Chg 1 Fz TI Mf #1 ① #1 ① NUC in eff Df 2689 Time 15.2 QE 326 Ammo Exp ①					
Fire order: Unit(s) to fire B , Mf #1 ① SHELL , Basis for corr _____, HES LOT XY , Distr _____, Sh NUC , Lot WY Chg L , Fz TI , _____ vol(s) _____ Rg spread _____, Time _____, Conc nr N 101													
Observer Corrections			Subsequent fire commands										
Dev	Height	Rg	Fz, MF	Corr	Chart df	Piece df	Rg	HB Corr	Si (+12)	Ti	EI	QE	Ammo exp
L30	D20	+200		0	2706		3630	-6	+6	16.1	334	340	②
R20	U10	-100			2698		3540	+3	+9	15.6	323	332	③
L10	U5	-50FF	SHELL NUC LOT WY		2697		3500	+54	+63	15.7	319	382	
										+1.3		+10	
										16.0		392	①
HOB CORRECTION						BAL CORRECTION							
+180 DESIRED HOB						+180 DESIRED HOB							
-(+115) ACHIEVED HOB (20.5)						+ 18 INITIAL VI							
+165						+(-5) NET HOB CORR							
+ 54 SITE (+165/3500)						+193 HOB ABOVE LEVEL PT.							
-(+48) ANGLE OF SITE (+165/3500)						+ 10 BAL QE CORR(+193+380)							
+ 6 COMP SITE						+ .3 BAL Fz CORR(+193+380)							
319 ELEVATION													
325 ELEVATION + COMP SITE													
15.7 FUZE SETTING FOR EL. 325 (GFT)													
Data for replot													
Coordinates			Altitude			Fuze			Conc nr				
Ammunition													
Type													
On hand													
Received													
Total													
Expended													
Remaining													

DA Form 6-16
1 AUG 62

PREVIOUS EDITION IS OBSOLETE.

Figure 150.2. FDC computers record.

APPENDIX III

AERIAL PHOTOGRAPHS

Section I. INTRODUCTION

1. General

This appendix provides the information required by field artillery units to plan for, request, and use aerial photographs. Other manuals containing pertinent information on the subject will be referred to by number. Only the aspects of aerial photographs directly related to artillery gunnery and not adequately covered elsewhere will be covered in detail in this appendix.

2. Planning

Factors involved in a unit's plan for aerial photographs are as follows:

a. Use. The purpose of which aerial photographs are required must be determined. The purpose will govern the type of photographs (FM 21-26), scale desired, and the number of prints required.

b. Area To Be Covered. The area in which the unit requires photographic coverage must be determined.

c. Terrain Features. Prominent terrain features suitable for use as control points in the area to be photographed must be considered.

d. Survey. The possible need for expansion of existing survey for additional ground control must be considered.

3. Requesting Aerial Photographs

Requests for aerial photographs are normally routed through organic intelligence channels (FM 11-40).

4. Use of Aerial Photographs

Aerial photographs are used by field artillery for—

a. Target Acquisition. A study of aerial photographs can disclose recent enemy construction, digging, movement (tracks and trails), and other activity not discernible to other available observation agencies. Targets can be identified on aerial photographs by their

size and shape and by shadows and tones. The locations of targets can be transposed to maps and firing charts by restitution (pars. 10-16, this app.).

b. Reconnaissance. Aerial photographs can provide recent information on the condition of roads, bridges, streams and other terrain features, and manmade objects. This information is an aid to map and visual reconnaissance.

c. Firing Charts. Vertical photographs (photomaps or mosaics) may be used as firing charts. When a map or grid sheet is used as a firing chart, aerial photographs are used to supplement the chart by providing additional horizontal locations.

5. Determining the Scale of Vertical Photographs

a. Determination of scale of vertical photographs is presented in FM 21-26 and TM 30-245.

b. Marginal data tabulated on photographs are presented in TM 30-245.

6. Converting Photographic and True Measurements

a. Setting Relationship on Military Slide Rule. Photographic measurements may be converted to true distance (and true to photographic) by use of a military slide rule or graphical site table. This is done by setting the photo distance (a number of units obtained with any convenient plotting scale) on the C scale of the slide rule directly over the true ground distance (meters) on the D scale. Once this setting has been obtained, any photographic measurement with the same plotting scale from the photograph can then be converted to true ground distance by moving the hairline to the photographic measurement on the C scale and reading the true ground distance under the hairline on the D scale.

b. Example. The true ground distance between two points identified on a photograph has been determined to be 1,500 meters. By using a plotting scale, the distance between the two points on the photograph is measured as 1,800 units. This photo distance (1,800) on the C scale is set over the true ground distance (1,500) on the D scale. To convert a photographic measurement of 2,100 units to true ground distance, 2,100 is located on the C scale and the true ground distance (1,750) appears directly below it on the D scale (fig. 151).

c. Computing Relationship. Photographic measurements may be converted to true distance (and true to photographic) by the use of the photo-ground relation. If the true (ground) distance between two points, A and B, which appear on a photograph is known, the distance measured (using any convenient units) on the photograph from A to B divided by the ground distance from A to B is the photo-ground relation and is expressed as a ratio as follows:

$$\frac{\text{AB photo (units)}}{\text{AB ground (meters)}}$$

The relation of the distance between any other two points on the photograph, C and D, to the ground distance between the same two points is the same ratio as for A and B; i.e.,

$$\frac{\text{AB photo (units)}}{\text{AB ground (meters)}} = \frac{\text{CD photo (units)}}{\text{CD ground (meters)}}$$

Therefore, if the photo distance from C to D is measured, the ground distance from C to D can be computed by transposing the previous equation to the following:

$$\text{CD ground (meters)} = \frac{\text{AB ground (meters)}}{\text{AB photo (units)}} \times \text{CD photo (units)}.$$

For example, the measured distance between two points on the ground is 1,500 meters, and the scaled distance between the same two points on the photograph is 1,800 units. To convert a photographic measurement of 2,100 units to true ground distance, the following equation is used:

$$\frac{X}{2100} = \frac{1500}{1800}, X = \frac{2100 \times 1500}{1800} = 1,750 \text{ meters true ground distance.}$$

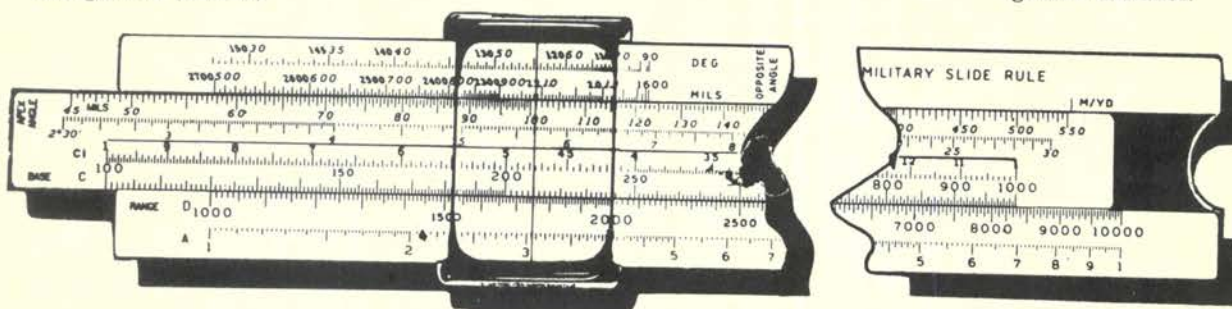


Figure 151. Method of using military slide rule for conversion of photographic measurements to true ground distance.

Section II. DISTORTION IN AERIAL PHOTOGRAPHS

7. General

An aerial photograph of absolutely level ground taken by a camera with its axis truly vertical would result in a picture in which the relative location of points on the picture would be the same as on the ground or a map (fig. 152). However, the vertical photograph is subject to distortion of detail. This is due mainly to tilt of the camera and to relief of the terrain photographed.

8. Tilt

If the camera is not level at the instant the photograph is taken, the scale of the photograph will not be uniform. In figure 153, it is evident that a horizontal line of a certain length appearing on a photograph near X will appear longer than a line of the same length appearing on the same photograph near Y, since X is nearer the camera than Y. When the tilt is small in a photograph, the resulting errors are negligible for artillery work. In a series of overlapping

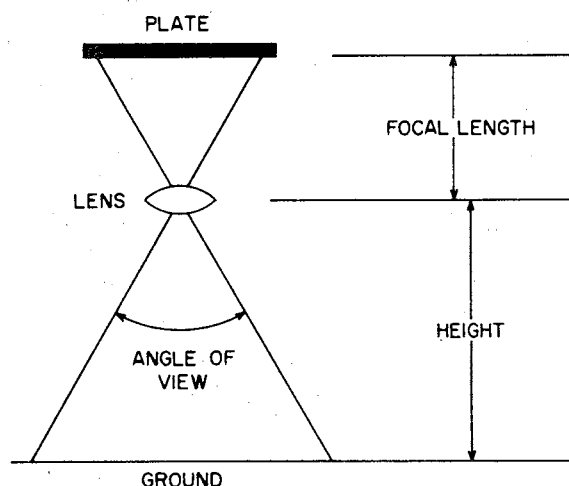


Figure 152. Photographic-ground relationship of a true vertical photograph.

photographs taken on a single flight, excessive tilt of the camera in taking one of the photographs is apparent if the center of that photograph is materially off the line of centers established by other photographs. If tilt is great enough to distort a vertical photograph, that photograph cannot be used for restitution of points onto a firing chart. Photographs taken with excessive tilt are not normally sent to using units, but, if an artillery unit does receive such photographs, corrected prints with the effect of tilt removed should be requested. Artillery units are not equipped to remove the effect of tilt from photographs. Tilt is discussed in more detail in TM 5-230.

9. Relief

a. General. The other important source of error in vertical photographs is relief. A point at a higher altitude than the datum plane appears farther from the photo center than it should. Considering figure 154 as any vertical section through the axis of the lens, Z will be recorded in its true position, the center of the photograph, regardless of its altitude. With reference to a horizontal datum plane (MN), an object (X) at a greater altitude will appear to be farther from the photo center than it actually is (X'); an object at a lower altitude will appear closer (Y will record as Y'). These displacements are radial from or toward the plumb point (point directly beneath the camera lens at the instant the photograph is taken—

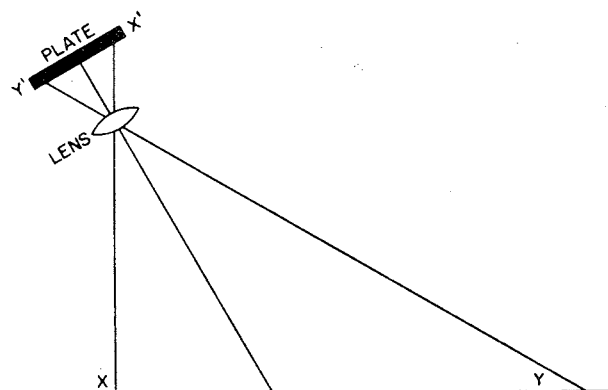


Figure 153. Effect of tilt.

also referred to as nadir, ground). If the tilt is small, the plumb point and the center of the photograph can be considered to be the same. For a given altitude of the airplane above the horizontal datum plane, the amount of displacement varies directly as the horizontal distance from the photo center (Z) and the vertical interval between the object and the horizontal datum plane. Directions of the radial lines, ZX and ZY, are not changed by the displacement of X and Y. The relief distortion of any particular point varies inversely as the altitude of the airplane varies.

b. Effect of Relief Displacement on Direction and Scale. The effect of relief is the displacement of images radially from or toward the center of the photograph. Considering figure

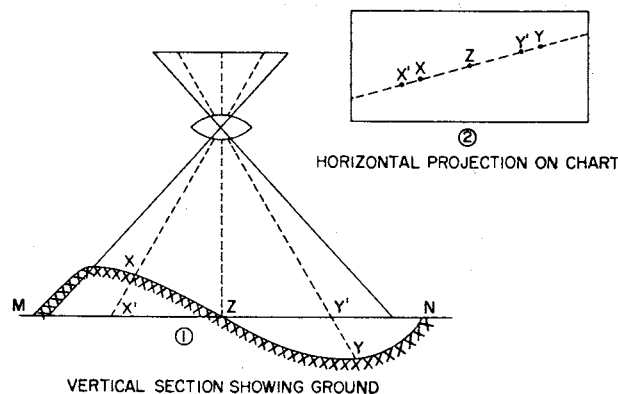


Figure 154. Displacement due to relief of ground.

155, the points X and Y are on the higher ground and the point Z is on lower ground than the center of the photograph (P). In the figure, X, Y, and Z represent the true locations of these points, whereas X', Y', and Z' represent the photographic locations. The lines X'Z' and X'Y' are not true direction lines, whereas PX', PY', and PZ' are true and Y'Z' is approximately true. Therefore, the directions of lines passing through or near the center of an average vertical photograph are substantially true. However, lines passing well away from the center and joining points of different altitudes whose images lie in the outer field of the photograph may show excessive errors in direction when relief is considerable. If the altitude from which the photograph was taken is known, the error may be corrected by a replot of the points to place them on the same datum plane.

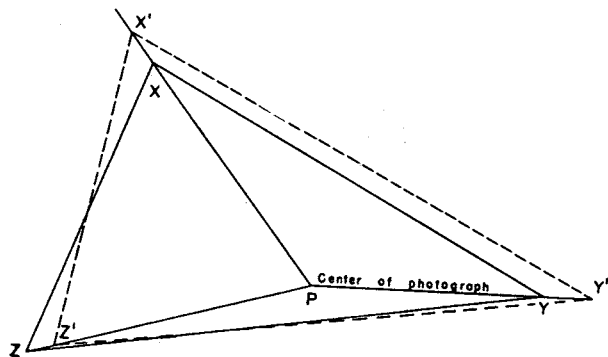


Figure 155. Effect of relief displacement on direction and scale.

c. *Determination of Relief Correction* (fig. 156). The amount of distortion, due to relief, can be found by solving the following proportion:

$$\frac{d}{D} = \frac{h}{H}$$

d is the displacement correction in meters (photo distance) radially toward (from) the center of the photograph.

h is the height of ground above (below) the horizontal datum plane.

D is the distance in meters (photo distance) from the center of the photograph to the point to be corrected. D may be measured with 1:25,000 or other convenient scale; the resulting value of d will be in the same units as D .)

H is the height of the camera lens above the horizontal datum plane. Usually, the altitude of the center of the target area is assigned arbitrarily as the horizontal datum plane and is used as the basis for distortion corrections.

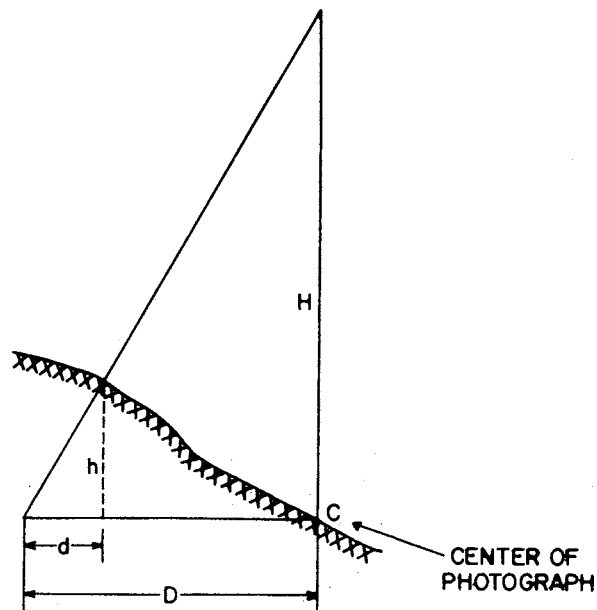


Figure 156. Determination of relief correction.

d. *Example of Correction for Relief Distortion* (fig. 157). An aerial photograph taken at an altitude of 28,000 feet above sea level is to be used to determine the relative location of points on the firing chart. By survey, point X has been determined to be 180 feet above the registration point (1, fig. 157). The selected datum plane, based on the approximate altitude

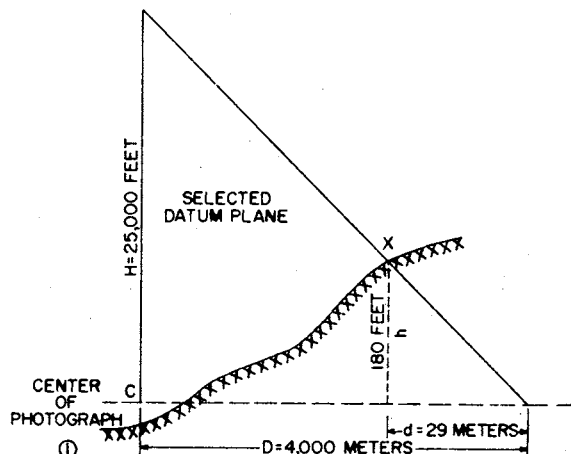
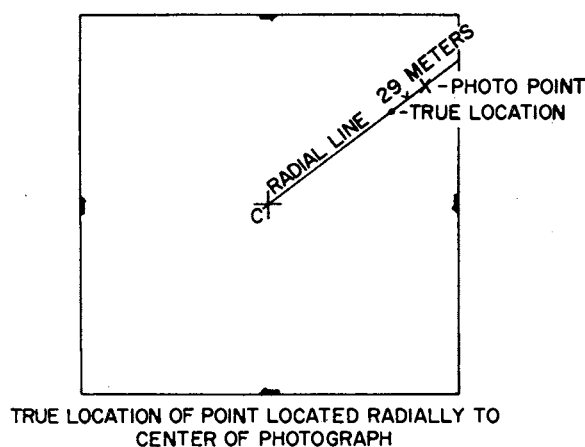


Figure 157. Example of correction for relief distortion.

of the registration point, is 3,000 feet above sea level. Therefore, the height of the camera lens is 25,000 above the datum plane. The distance from point X to the center of the photograph is scaled as 4,000 meters. Point X will be plotted 29 meters $d = \frac{180}{\frac{4000}{25000}} = 28.8$ along a radial

line toward the center of the photograph from its photographic location (2, fig. 157).



TRUE LOCATION OF POINT LOCATED RADially TO CENTER OF PHOTOGRAPH

②

Figure 157—Continued.

Section III. RESTITUTION

10. General

a. Restitution is the process of transferring points from aerial photograph to a chart, one photograph to another photograph, or a chart to a photograph. Restitution may require the use of one or more photographs, depending on the method used.

b. One of the most accurate methods of restitution is the radial line method, which requires the use of overlapping vertical photographs.

c. A single vertical photograph is used whenever the target does not appear on overlapping vertical photographs. There are four methods of restitution which involve the use of single vertical photographs only. These methods are listed in order of accuracy as follows:

- (1) Alternate polar plot.
- (2) Polar plot.
- (3) Proportional dividers.
- (4) Tracing paper resection.

d. In the restitution procedures described in paragraphs 11 through 15 of this appendix, critical points (photo centers, restitution points, targets, etc.) may be pricked through to a piece of overlay paper; the overlay paper may then be used in lieu of the photograph. The procedure will preclude having to draw any lines on the photo except those lines necessary to locate the photo center.

11. Radial Line Method

For practical purposes, the combined effects of relief and tilt in photographs taken with a camera slightly tilted is assumed to cause displacements along radial lines passing through the centers of the photographs. This assumption is used in the radial line method of restitution to determine accurately the map position of a point appearing in the overlap of two aerial photographs taken at different camera positions. This is one method of restitution that will correct for both tilt and relief; however, the method is not accurate if the tilt is greater than 3° or if the point sought falls on or near the line joining the centers of the two photographs, because this makes it difficult to obtain a good angle of intersection. To restitute a target which appears on two overlapping vertical photographs, the following procedure is used:

a. Mark the photo center of each photograph. The photo center is the geometric center of the photograph and is determined by the intersection of lines through the corners of the photograph or through the fiducial marks along the edges of the photograph (1, fig. 158).

b. Identify on each photograph three control points whose chart locations are known. A different set of points may be selected for each photograph, or the same points may be used. The points selected should be well out from the center of each photograph and widely distrib-

uted. Draw radial lines or rays from center (C) of each photograph to the photographic locations of the control points (XYZ) (2, fig. 158).

c. Place tracing paper over the firing chart and prick the chart locations of the control points on the tracing paper (3, fig. 158).

d. Place the prepared tracing paper over one photograph so that the rays on the photograph pass through the corresponding control points on the tracing paper (4, fig. 158).

e. Draw a ray on the tracing paper from the center of photograph 1 through the target to be restituted (T) (4, fig. 158).

f. Repeat steps in d and e above on photograph 2 using the same tracing paper (5, fig. 158). The two photo centers and the ray from each photo center to T now appear on the tracing paper. Intersection of the rays through T gives the tracing paper location of the target to be restituted.

g. Orient the tracing paper over the chart (control point over control point) and prick through the intersection of lines, thus transferring the target to the chart (6, fig. 158).

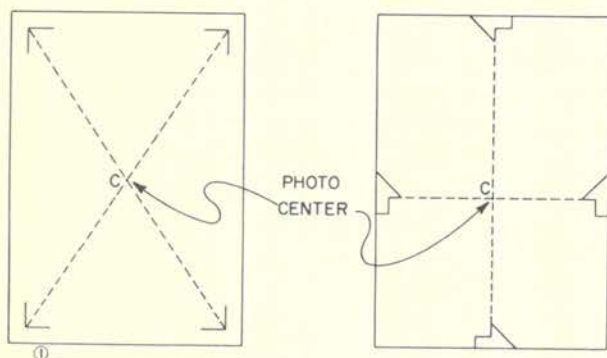


Figure 158. Radial line restitution.

h. Another acceptable procedure for radial line restitution is one using two pieces of tracing paper, one with each photograph. The procedure for the alternate polar plot method (par. 12, this app.) is followed until both pieces of tracing paper are correctly oriented over the chart. The intersection of the two photo center-target lines (one on each piece of tracing paper) is then pricked through to the chart.

12. Alternate Polar Plot

The most accurate method of restitution from a single vertical photograph is the alternate

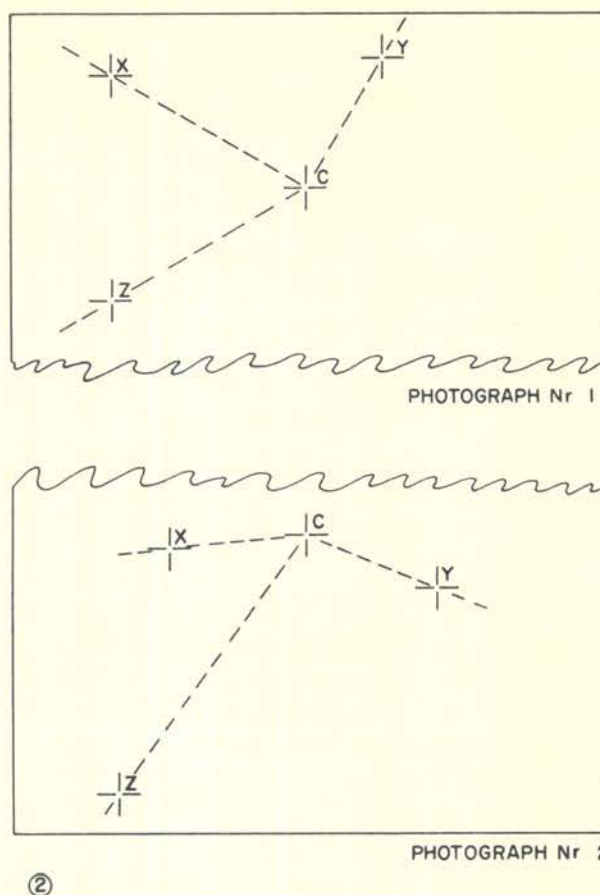


Figure 158—Continued.

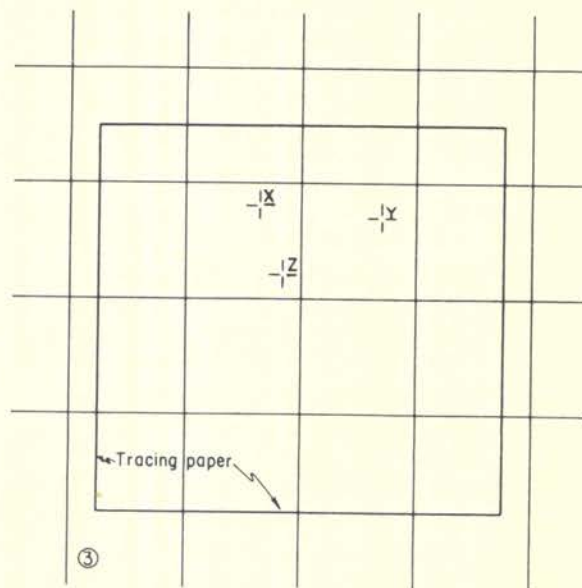


Figure 158—Continued.

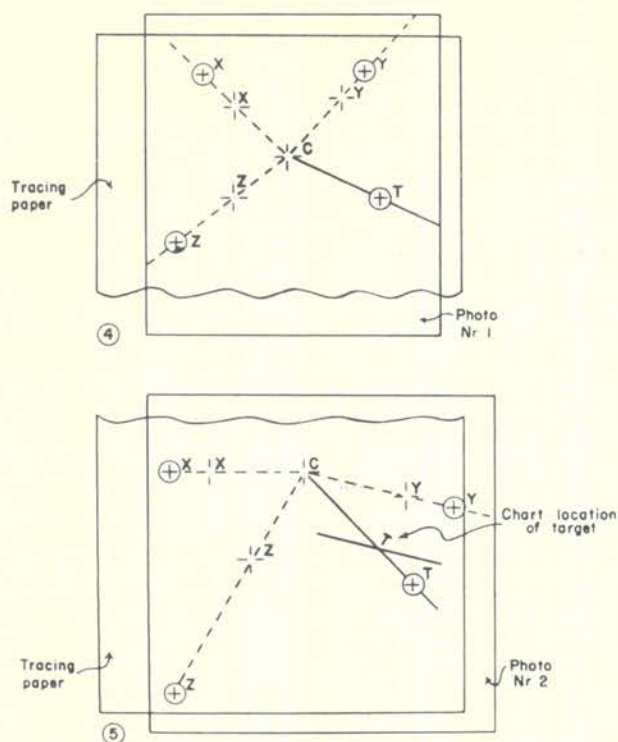


Figure 158—Continued.

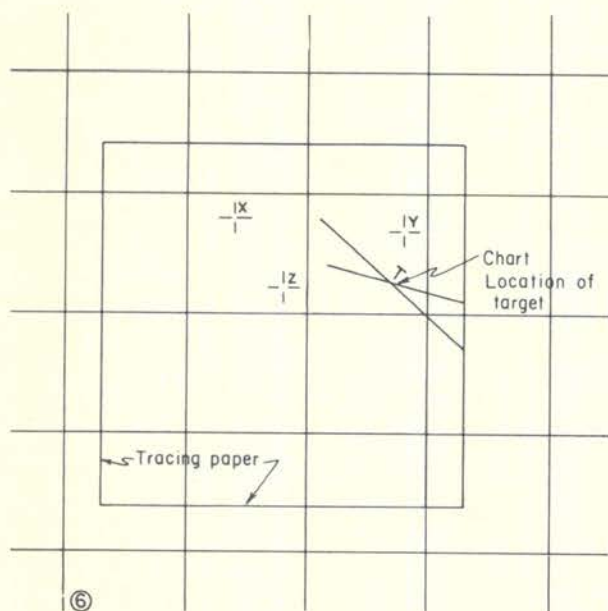


Figure 158—Continued.

polar plot method. This method partially eliminates errors due to distortion by using only radial lines from the photo center as bases for polar plotting. The procedure for the alternate polar plot method is as follows:

a. At least three points whose chart locations are known are identified on the photograph, and the photo center is determined and marked. Radial lines are drawn on the photograph from the photo center C to the three known points (XYZ) and the target (1, fig. 159).

b. An overlay is made from the photograph showing the photo center, and the radial lines are drawn from the center through the three points (XYZ) and the target (2, fig. 159).

c. The overlay is then placed over the chart and moved until the three rays pass through the control points on the chart (3, fig. 159).

d. The procedure for transferring points is to convert the photo distance to chart distance (par. 6, this app.) and plot the chart distance on the ray drawn on the tracing paper from photo

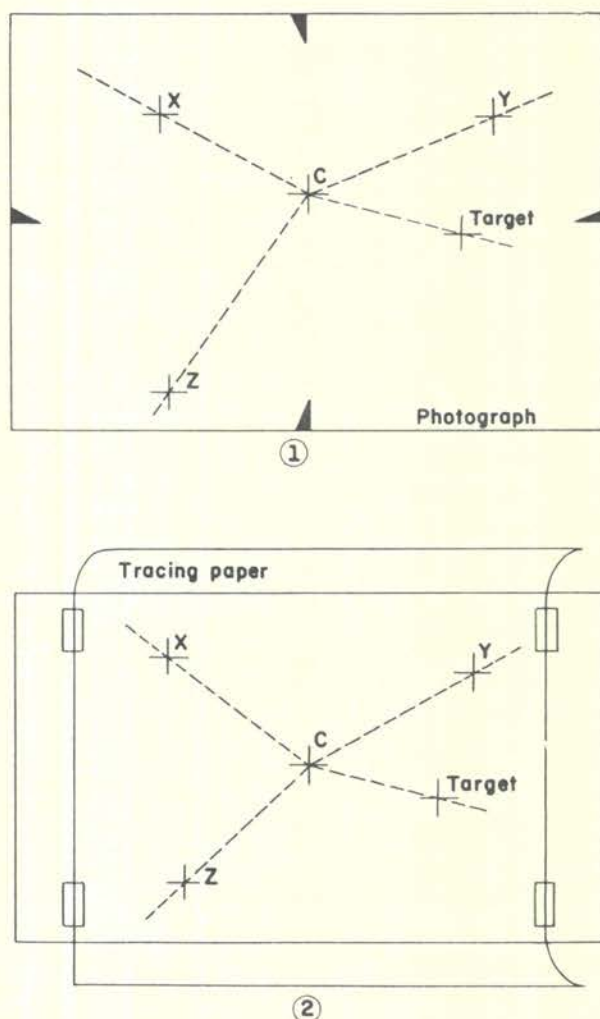


Figure 159. Alternate polar plot restitution.

center to target and pin prick through the overlay paper (3, fig. 159).

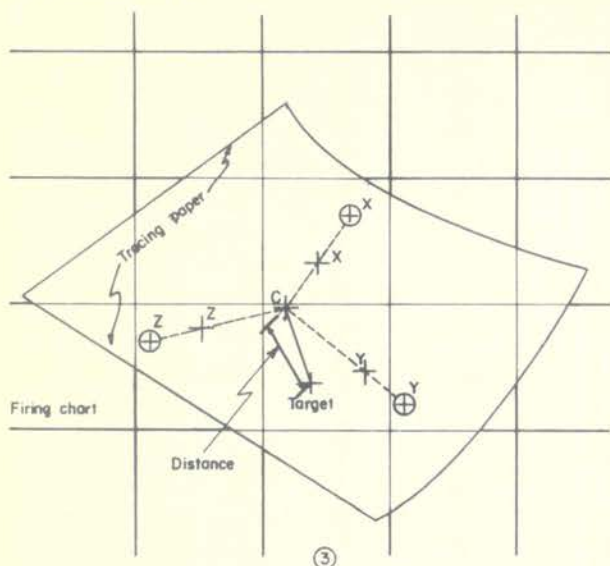


Figure 159—Continued.

13. Polar Plot

Another method of restitution from a single vertical photograph is the polar plot method. Since the angles used are not radial, inaccuracies from relief and tilt may be introduced. As illustrated in figure 160, the procedure is as follows:

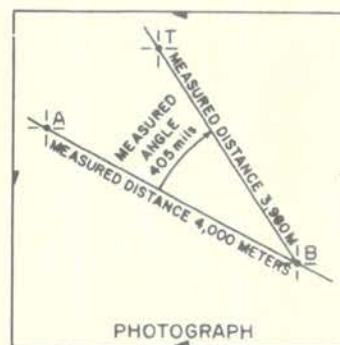
a. Two or more well-separated points (A and B), whose chart locations are known, are identified on the photograph and a line is drawn between these two points on both the photograph and the chart. To reduce errors of relief and tilt, these points should be at about the same altitude, and the line established should pass close to the center of the photograph.

b. The line of the photograph is extended to enable shifts and distances to be measured from either of the points with an angle-measuring device (protractor, range-deflection protractor, or GFT fan).

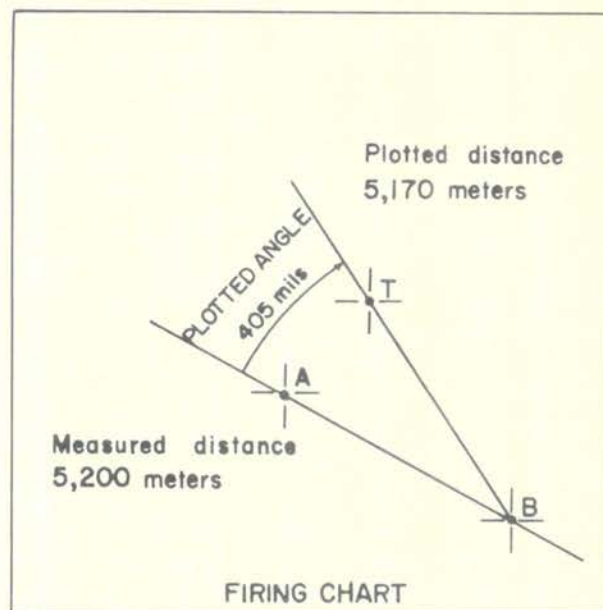
c. The difference in scale between the photograph and chart is compensated for by measuring the photograph and chart distances and by setting up a relation between the two on a slide rule (par. 6, this app.). In the example shown in figure 160, photo distance (4,000 meters) is placed on the C scale over chart distance (5,200 meters) on the D scale.

d. To restitute a point (T) from the photograph to the chart, the angular shift from the known line and the distance are measured from whichever known point will give the smallest angle and the largest distance. In this case, the measurement is made from point B, and the results are an angular shift of 405 mils right of line BA and a photo distance of 3,980 meters.

e. The photo distance is converted to chart distance by using the relationship set up on the slide rule and the procedure described in paragraph 6, this appendix. By moving the hairline to the photo distance of 3,980 meters on the C



①



②

Figure 160. Polar plot restitution.

scale, the chart distance of 5,170 meters is read directly below it on the D scale.

f. The desired point T is plotted on the chart by using the measured shift of 405 mils right of line BA and the chart distance of 5,170 meters from point B.

14. Proportional Dividers

The most rapid method of restitution is by use of proportional dividers (fig. 161). This instrument consists of two legs, each pointed at both ends, which are held together by means of a central pivot. When the legs are opened in the form of an X, either end of the instrument forms a pair of ordinary dividers. The position of the pivot along the legs can be varied to produce any desired ratio. Once the pivot of the dividers is set to the proper photograph-chart ratio, all points on any particular photograph may be restituted to the chart without disturbing the adjustment of the pivot. With the pivot at a fixed setting, distances are taken off the photograph with one end of the proportional dividers and laid off on the chart with the other end. These photo distances are subject to errors of tilt and relief. To restitute points from photograph to chart, proceed as follows:

a. Select restitution points which appear both on the photograph and the chart. In figure 161, the two points selected are the bridge and the fence corner.

b. By trial and error, adjust the pivot so that, when the points on the photograph end of the dividers match the two restitution points on the photograph, the points on the chart end of the dividers will match the two restitution points on the chart.

c. Using the photograph ends of the dividers (1, fig. 161), lay off the distance from the first restitution point to the point to be located. Without disturbing the adjustment, reverse the dividers and strike an arc on the chart from the first restitution point in the direction of the point to be located (2, fig. 161).

d. Repeat the procedure for the second restitution point. The location of the point on the chart is at the intersection of the two arcs drawn. If a third restitution point is available, another arc is drawn to give a check on the location determined from the first two.

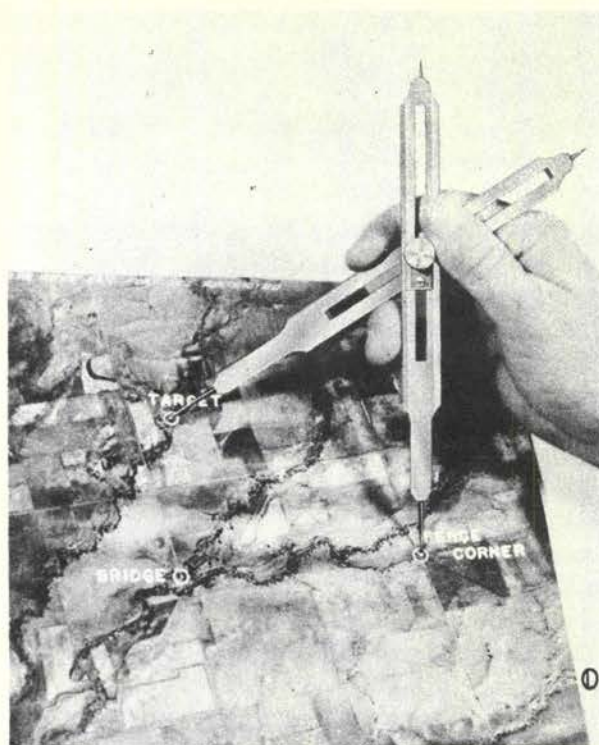


Figure 161. Restitution with proportional dividers.

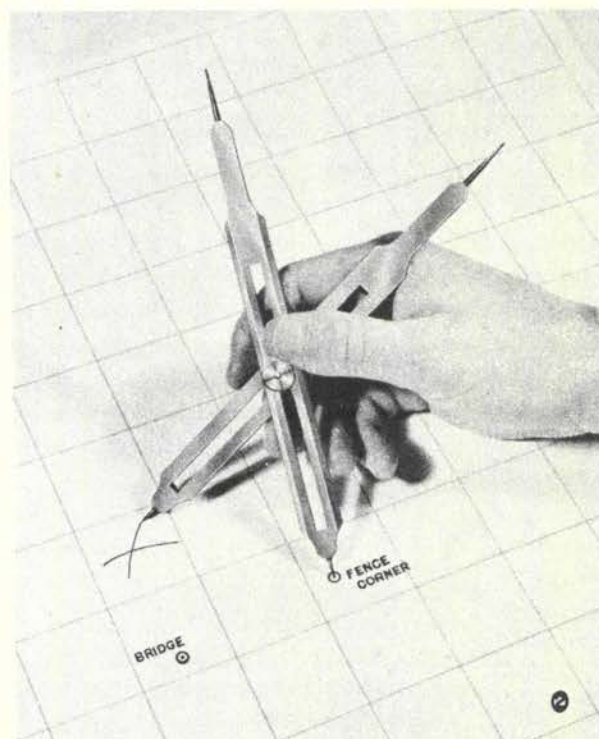


Figure 161—Continued.

15. Tracing Paper Resection

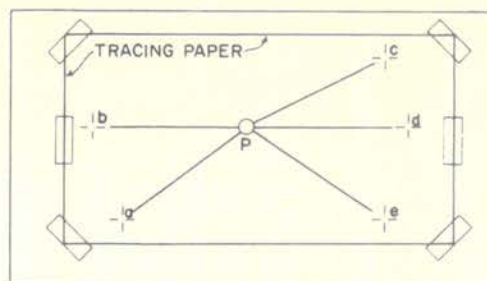
a. Points within a limited area appearing on a vertical photograph may be plotted roughly on a map or firing chart by the use of tracing paper resection.

b. To locate a point (P) (fig. 162), identify on the photograph at least 3 points (preferably 5) that appear on the map or firing chart. Mark on a sheet of tracing paper the photographed position of these points and the point to be located. This is accomplished best by tacking the photograph over the tracing paper and pricking a pin through each point. On the tracing paper, draw rays from the point (P) to each of the known points, such as a, b, c, d, and e. Place the tracing paper on the map or chart so that the ray to each of the known points passes through the map or chart location of the corresponding point. The point (P), represented by the intersection of rays, is then in its relative position to the known points, and its position may be pricked onto the map.

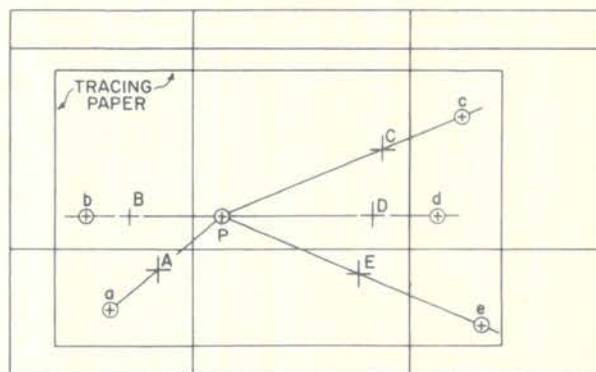
c. This method is subject to errors of tilt and relief. The error of location can sometimes be reduced by selecting more than the minimum of three known points. Accuracy can be improved by selecting restitution points that are widely separated, and are near the altitude of the mean datum plane.

16. Vertical Control

Normal methods of restitution do not include adequate means of determining vertical control. Use of a stereoscope may aid in determination of relative heights. High obliques, when



① PHOTOGRAPH



② TRACING PAPER OVERLAY

Figure 162. Tracing paper resection.

gridded, can be used to supplement vertical control. If a map is available and points can be identified on both map and photograph, vertical control is relatively simple. A pantograph (TM 5-230) can be used, if available, to transcribe contour lines from a map to a vertical photograph. Survey can also be used to establish vertical control, provided points are on terrain which is accessible, or visible, to the survey party.

Section IV. OBLIQUE PHOTOGRAPHS

17. General

Oblique photographs are those taken with the axis of the camera intentionally tilted from the vertical position. Oblique photographs which show the horizon are high obliques and those which do not show the horizon are low obliques.

18. Characteristics

The primary characteristics of oblique photographs are as follows:

a. Oblique photographs may be taken from either air or ground observation posts.

b. A special camera is not necessary for taking oblique photographs.

c. Relief is more readily recognizable on an oblique photograph than on a vertical photograph.

d. Oblique photographs are limited by their size and perspective to a useful depth of about 10,000 meters.

19. Uses

Oblique photographs are used for the following purposes:

a. Reconnaissance. Use of oblique photographs to supplement visual reconnaissance enables a commander to more nearly see the terrain as it appears to an observer in a frontline position.

b. Briefing. Oblique photographs are used to brief ground and air observers and to designate objectives, phase lines, boundaries between units, zones of fire, zones of observation, and observation posts.

c. Terrain Sketches. Observers can use oblique photographs as terrain sketches. When a copy of the photograph is available to the fire direction center, it facilitates the exchange of battlefield information and enables the S3 and S2 to see the terrain as the observer sees it.

20. Mil-Gridded Oblique Photographs

a. Mil-gridded oblique photographs (fig. 163) are made by the Air Force by contact printing the negative through a transparent mil grid. Mil-gridded oblique photographs are used in conjunction with firing charts to determine the horizontal and vertical locations of points (fig. 164). Horizontal locations of points obtained from gridded oblique photographs are not as accurate as those obtained from vertical photographs. Therefore, oblique photographs should not be used to determine horizontal locations when vertical photographs are available. Gridded oblique photographs, however, may be used to good advantage in conjunction with firing charts for the purpose of determining altitudes.

b. The following terms are used in conjunction with mil-gridded oblique photographs:

(1) *Plumb point*—The point on the ground

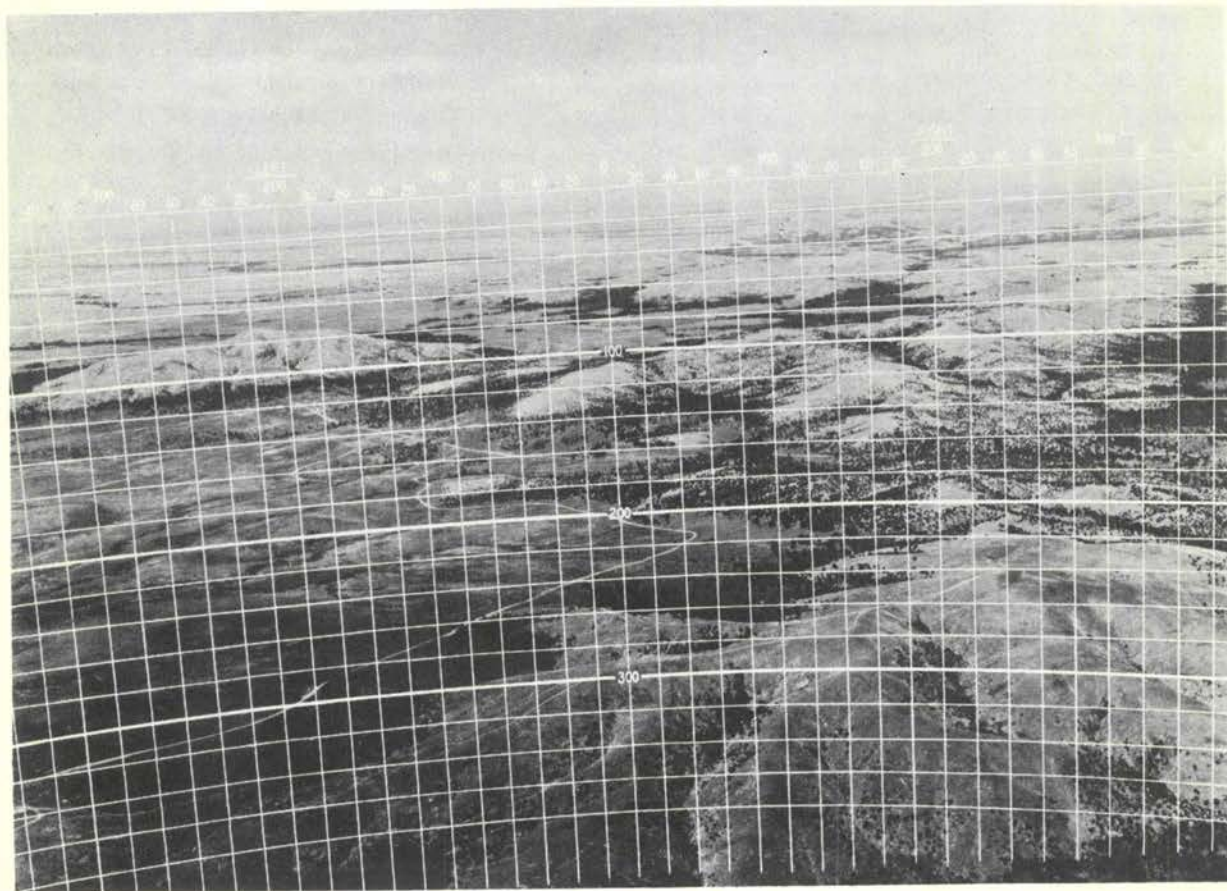


Figure 163. Mil-gridded oblique photograph.

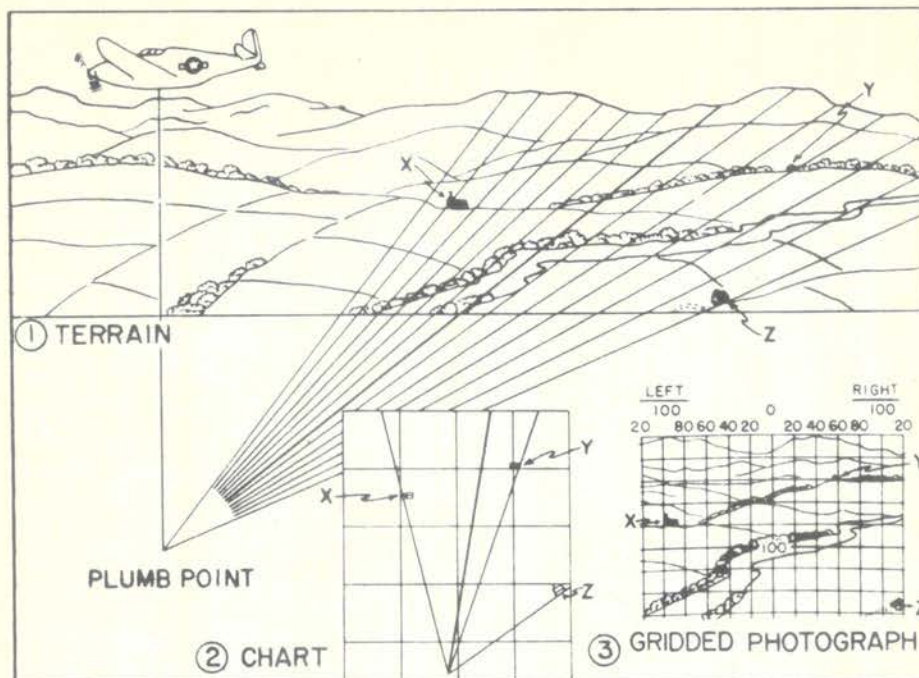


Figure 164. Mil-gridded oblique photograph used in conjunction with firing chart.

vertically beneath the perspective center of the camera lens.

- (2) *Center line*—The map projection of the vertical plane that contains the axis of the camera at the instant the photograph was taken. On the photograph, the center line appears as the zero line from which right and left angular measurements are taken. On the chart, the center line appears as the direction line from which the right and left angular measurements are plotted.

21. Horizontal Locations

a. Orientation of Photographs. Oblique photographs are oriented by determining the chart locations of plumb points and the chart direction of center lines.

- (1) *Location of plumb points.* The tracing paper method of resection can be used to determine the chart locations of plumb points. The chart locations of three or more ground control points appearing on each photograph are necessary. These chart locations may be determined by survey or may be taken from a map or vertical photo-

graph. The relative locations of the ground control points on the observed firing chart may be determined by firing. In preparing the tracing paper to be used in the resection, the horizontal angle from the center line to each ground control point is read on the mil grid and plotted on the tracing paper with an angle-measuring device. The tracing paper then is placed over the chart in a position so that the ray toward each control point passes through the chart location of the same point. The plumb point is pricked through to the chart.

- (2) *Location of center lines.* With the tracing paper in the same position as in (1) above, any convenient point on the center line is pricked through to the chart.

Note. Each plumb point and center line must be labeled with its photograph number; center lines are marked with identifying arrows.

b. Transposition of Points from Oblique Photographs to Charts.

- (1) *Point designation.* Oblique photograph references include a photograph num-

ber and horizontal and vertical angles; for example, "Photo 58, L156042." The photograph number designates the photograph from which the reading was taken. The letter "L" or "R" indicates a reading left or right of the center line. The first three figures represent the horizontal angle from the center line. The last three figures represent the vertical angle from the 0 or level line.

- (2) *Plotting the point.* Points are located from oblique photographs by the plot of the intersection of two or more lines of sight.

Example: The following message has been received from an observer: PHOTO 59, R210118, INFANTRY PLATOON WITH HEAVY WEAPONS, REQUEST BATTALION, FIRE FOR EFFECT. Fire direction personnel identified the same point on photograph 60 as L060 and on photograph 61 as L305. The target should be plotted as in figure 165.

22. Determination of Altitudes

When mil-gridded oblique photographs are used in conjunction with maps having suitable

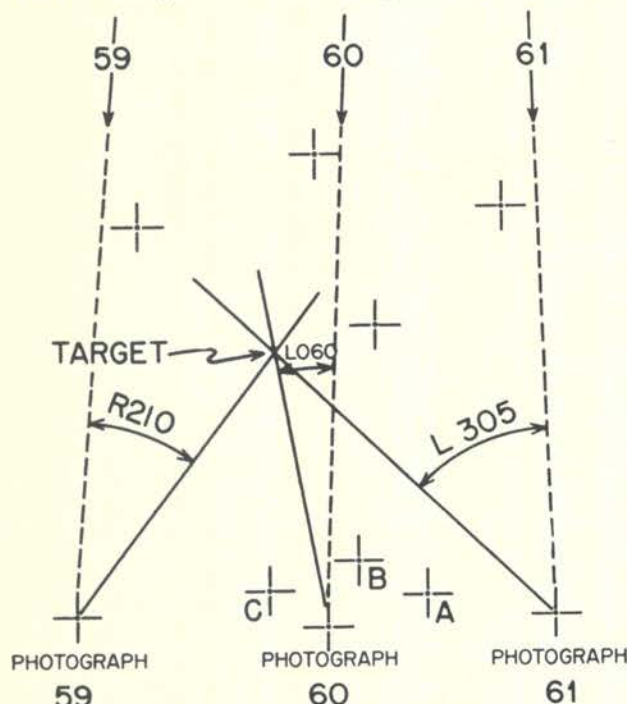


Figure 165. Location of a target on the firing chart.

vertical control, map altitudes are used. If maps are not available, the altitude of the camera is computed and then the vertical interval between the camera and the target is subtracted from the altitude of the camera.

a. Altitude of the Camera. To determine the altitude of the camera, it is necessary to have one point which can be identified on the photograph and of which the chart location and altitude are known. The vertical interval between the selected point and the camera is determined by using the mil relation. The interval plus the known altitude of the point is the altitude of the camera. For example, a house, the altitude of which has been established by survey, appears at a vertical angle of 100 mils on photograph 59. Its distance on the firing chart from the plumb point of photograph 59 is 3,500 meters. Figure 166 shows the relations that exist.

$$\begin{array}{rcl} \text{Vertical interval } (3.5 \times (+100)) & = & +350 \text{ meters} \\ \text{Altitude of house (survey)} & = & 300 \text{ meters} \\ \text{Altitude of camera } (350 + 300) & = & 650 \text{ meters} \end{array}$$

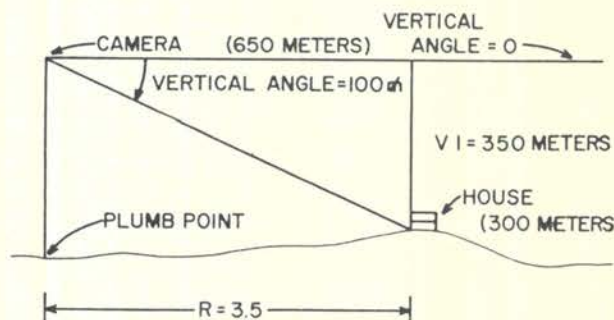


Figure 166. Determination of the altitude of the camera.

b. Altitude of the Target. The altitude of a target cannot be determined from a mil-gridded oblique photograph until the altitude of the camera has been determined. When this altitude has been established, the altitude of any target is determined by subtracting the vertical interval between the target and the camera from the altitude of the camera. For example, a target is reported by reference to an oblique photograph, as PHOTO 59, R210118, Chart distance, after plotting, from the plumb point is 3,200 meters.

$$\begin{array}{rcl} \text{Altitude of camera (a above)} & = & 650 \text{ meters} \\ \text{Vertical interval } (3.2 \times (-118)) & = & -378 \text{ meters} \\ \text{Altitude of target } (650 - 378) & = & 272 \text{ meters} \end{array}$$

APPENDIX IV

NAVAL GUNFIRE SUPPORT

Section I. INTRODUCTION

1. General

Naval gunfire and air support are required to replace artillery support initially in an amphibious operation or to reinforce artillery in coastal operations. When naval gunfire is used for support of land forces, the Navy is responsible for control and command. Naval gunfire should be requested only when targets cannot be engaged adequately by field artillery.

2. Characteristics of Naval Gunfire Support

In order to utilize naval gunfire effectively, it is necessary to understand the inherent advantages and disadvantages of the system. These are as follows:

a. Advantages.

- (1) *Mobility.* Within the limits imposed by hydrography, the firing ship may be positioned for the best support of the troops. This ability to maneuver allows the selection of the most favorable gun-target line, and is an important factor when planning for the support of widely separated beaches.
- (2) *Rates of fire.* The large volume of fire which can be delivered in a relatively short period of time is a distinct advantage when delivering neutralization fires. These high rates of fire are due to power loading and mechanical hoisting equipment. In some of the newer ships, the entire process from magazine to muzzle is completely automatic.
- (3) *Fire control equipment.* Precision fire control equipment permits accurate fires, both direct and indirect, to be delivered in support of the landing force. These fires can be delivered

while the ship is underway as well as at anchor.

- (4) *Caliber of guns.* A variety of weapons, varying from 3-inch to 16-inch guns, may be available to permit selection of the caliber best suited to accomplish the mission.
- (5) *Ammunition.* The different types of projectiles, powder charges, and fuzes available in most of the calibers permit selection of the optimum combination for the attack of any target.
- (6) *High velocity.* The high initial velocity of the naval gun projectile makes it suitable in the direct fire role for the penetration and destruction of material targets, particularly those presenting appreciable vertical face.

b. Disadvantages.

- (1) *Communications.* All communications between the ship and the shore is dependent upon radio. This single means of communication is susceptible to interruption by equipment limitations, enemy electronic warfare, and unfavorable atmospheric conditions.
- (2) *Changing gun—target line.* When the ship is firing while underway, the line of fire may change relative to the front line. Under certain conditions, this can cause cancellation of the fire mission because of the danger to friendly troops.
- (3) *Fixing ship's position.* The accuracy of naval gunfire depends upon the accuracy with which the position of the firing ship has been fixed. In areas where navigational aids are lacking, there will be appreciable inaccuracies in unobserved fires and in the initial salvos of observed, indirect fires. Em-

ployment of radar beacons will reduce this problem.

- (4) *Ammunition capacity.* Magazine capacity of fire support ships is limited. While a relatively high percentage of total ammunition is made available for gunfire support, some must be retained for protection against enemy air or surface attack.
- (5) *Hydrography.* Unfavorable hydrographic conditions such as shallow waters, reefs, shoals, etc., may force the firing ship to take an undesirable firing position with respect to the target area. The presence of mines can require that initial firing positions be farther from the target area than is desirable.
- (6) *Weather and visibility.* Bad weather and poor visibility make it difficult to determine ship position by visual means and reduce the observer's opportunities for locating targets and adjusting fires.

c. Other Characteristics. The following characteristics of naval gunfire are advantageous in some respects, but disadvantageous in others:

- (1) *Flat trajectory.* The relatively flat trajectory of the naval gun results in accuracy which is essential to destruction missions. However, this flat trajectory is unsuitable for the attack of targets in defiladed positions and restricts the attack of targets close to the front lines when the gun-target line passes over friendly troops.
- (2) *Range and deflection pattern.* The dispersion pattern of the naval gun is comparable to the dispersion pattern of the artillery weapon. The long narrow shot pattern is particularly effective when fire can be brought to bear upon the long axis of the target. It also allows fire to be brought close to friendly front lines when the gun-target line parallels those lines. Conversely, if the ship is firing while underway, the long range pattern may

endanger friendly troops. The long range pattern also reduces the degree of closeness to front lines to which fires may be safely delivered when the gun-target line is not parallel to front lines.

3. Naval Weapons

A variety of weapons is available for naval gunfire support, the various combinations being determined by the type of vessel. Among the larger calibers of weapons available on United States Navy vessels are 3-inch, 5-inch, 6-inch, and 8-inch guns; 5-inch rockets; and various guided missiles.

4. Ammunition

Types of projectiles, charges, and fuzes available vary according to the caliber of the weapon. Generally, the usual combinations of projectile and fuze employed in field artillery are available in naval ammunition.

a. Guns of 5-inch caliber and larger are provided with high-capacity ammunition, which is comparable to field artillery high explosive projectiles of equivalent size. Armor-piercing projectiles, normally used in fleet surface engagements, are available for all guns of 6-inch caliber and larger. Illuminating shell is available for the 3-inch, 5-inch, and 6-inch guns; white phosphorous shell is available for the 3-inch and 5-inch guns.

b. Full and reduced charges are available for calibers of guns above 3 inches. The reduced charge for the 5-inch gun produces 1,200 feet per second muzzle velocity and a trajectory similar to that of charge 6 for the 105-mm howitzer and charge 5 for the 155-mm howitzer.

c. The fuzes vary with different calibers and projectiles but generally include quick, delay, time, and variable time (VT). A point detonating fuze corresponding to the artillery fuze quick is available for all naval high-capacity (high-explosive) projectiles. All delay fuzes are base detonating and vary in length of delay according to type of projectile and caliber. The time fuze is the mechanical type and is available

for all high-capacity projectiles of 5-inch and larger caliber. The VT fuze is available for the 3-inch, 5-inch, and 6-inch guns. Because of the design of the VT fuze, the height of burst varies from 10 feet at 6,000 yards to 30 feet at 12,000 yards. Use of VT fuze in shore bombardment at ranges less than 6,000 yards is not recommended. Even at the greater ranges, the danger of a premature firing of a VT fuze over the heads of troops should be clearly recognized.

5. Prearrangement

a. Rehearsals for observers, communication personnel, and fire support ships should be held before each operation to develop teamwork and mutual understanding. The naval gunfire spotter (para. 6e(1), this app.) and other observers must be furnished the necessary maps or map substitutes to be used in target designation. They also must be furnished the grid systems and codes that are to be used and be familiar with them. They must know the plan of communication between themselves and the firing ship. They must be told about the calibers of weapons to be used and how they can get fire support of vessels other than those directly supporting the action.

b. Preparation fires (preliminary bombardment) are placed jointly under Army requirements. Planning of naval gunfire support is started as soon as the directive for the conduct of an amphibious operation is received. An exchange of staff officers between appropriate headquarters aids the planning of naval gunfire support.

6. Naval Organization for Combat

a. Naval ships are assigned support missions in much the same way that artillery is organized for combat. These missions consist primarily of direct support and general support of a troop unit. When ships are placed either in direct or general support of troop units, the selection of targets, the timing of fires on the targets, specification of line of fire (when not inconsistent with safe navigation), and the adjustment of fires are functions of the supported troop units.

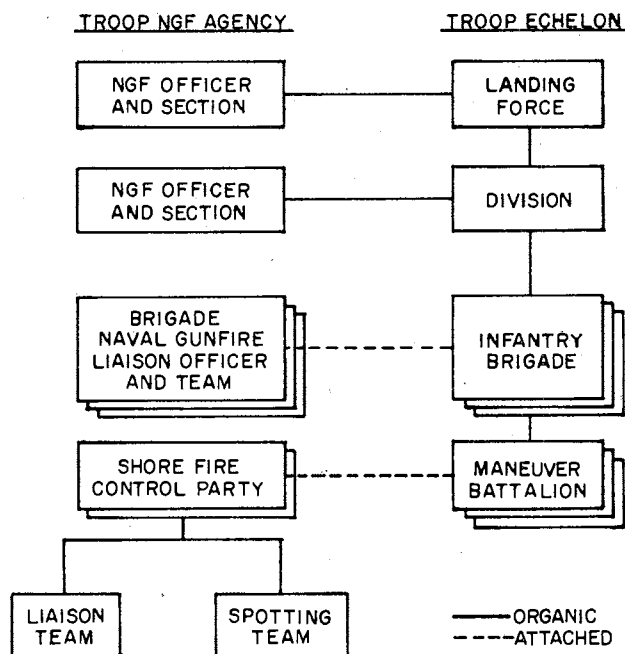


Figure 167. Example of five support areas and zones of responsibility.

b. A ship in direct support of a specific troop unit (normally of battalion or comparable size) delivers both prearranged and call fires. Call fires are conducted and adjusted by a shore fire control party of the supported unit or by an air spotter. Although members of the Shore Fire Control Party (SFCP) (para. 8) are specifically trained in the conduct of naval gunfire, simplified and standardized procedures are such that any trained supporting arms observer can effectively adjust the fires of a ship.

c. General support missions are assigned to ships supporting units of regimental size or larger. Regimental naval gunfire liaison officers may adjust the fires of these ships. However, the normal procedure is to have the fires of the general support ship adjusted by an air observer or for the liaison officer to assign the fires of the ship to a battalion SFCP for fire missions. In the latter case, upon completion of the mission(s), the ship reverts to general support. Fire may also be observed and adjusted directly from the ship when the target can be observed from the ship. The primary purpose of general support assignment is to

give the commander a means of adding depth to the fires of direct support ships without necessity for requests to higher echelons of command. Fire missions against targets of opportunity are conducted directly by the fire support ship as provided for in the naval gunfire support plans. Prearranged fires are delivered in accordance with a schedule which is an appendix to the naval gunfire plan.

d. Closely related to the assignment of gunfire support missions is the assignment of sea areas in which the ships are to operate. These areas are called Fire Support Areas (FSA), are given numbers (usually Roman numerals) or names, and are shown on the operations overlay. They are selected to provide space for the execution of the support mission and for maneuver room to evade enemy fires. They should be located in such a way as to minimize interference with the ship-to-shore movement. However, in the event that sea space is restricted, it may prove advantageous to use Fire Support Stations (FSS) where in the firing ships are placed and maintained in exact, predetermined locations. Such a system can be used to station ships within boat lanes or other areas where maneuvering room is restricted by other considerations.

7. Zones of Responsibility

The land in the objective area is divided as required into naval gunfire zones of responsibility. Fire support units or individual ships are assigned zones of responsibility and are responsible for destroying or neutralizing known enemy installations and for attacking targets of opportunity in their zones. The size and shape of a zone of responsibility will depend upon the factors described in the following paragraphs.

a. Boundaries. In order to permit ready identification by the spotter and for the fire support ships, the boundaries of the zones of responsibility must be recognizable both on the terrain and on the map. The use of terrain features, consistent with other considerations, will assist considerably in accomplishing this. It may be necessary to divide a large zone of responsibility into two or more smaller zones

due to the considerations discussed below. The boundaries of zones of responsibility of direct support ships should correspond to the zones of action of the landing force units supported.

b. Size. The size of each zone should be such that the fire support ship, or ships assigned to observe and/or destroy targets, will be able to accomplish the mission in the time allocated. When the zones of responsibility are delineated, the known or suspected targets scheduled for destruction in each zone are plotted, and then the number and type of targets are compared to the capability of the ship in conducting destructive missions within the time allotted.

c. Visibility. Observation from seaward is a desirable feature for zones of responsibility since it permits a ship to deliver more accurate and rapid fire.

d. Accessibility to Fire. The zones of responsibility must be accessible to the trajectory of the fire support ships assigned to the zone.

e. Assignment of Targets. After delineating the boundaries of the zones of responsibility and plotting the known or suspected targets, the plot is examined to insure that high priority targets are not located on the boundaries. Important targets on or near a boundary are clearly assigned to a specific ship to prevent its escaping destruction or being fired upon by more than one ship.

8. Organization

The naval officer in tactical command (OTC) commands the fire support ships from his command ship. The amphibious task force commander (advance force/attack group commander) commands the naval gunfire (NGF) ships. Based on the request of the landing force, he will assign direct or general support missions to the ships of the amphibious task force (advance force/attack group). Control ashore is exercised by specially trained personnel furnished by the landing force and the Navy.

a. Control of naval gunfire is exercised by, and passes to, different commands and agencies as the operation progresses. Arrangements

must be made to provide each commander with proper facilities for control of naval gunfire.

- (1) *Pre-D-Day bombardment.* The advance force commander is responsible for control during pre-D-day bombardment. Control is normally exercised through the advance force supporting arms coordination center.
- (2) *Transfer of control responsibility upon arrival of amphibious task force commander.* The amphibious task force commander assumes responsibility for control of naval gunfire upon his arrival in the objective area. Control is exercised through the supporting arms coordination center on board ship.
- (3) *Attack groups.* When attack groups are formed and separate landing areas are designated, the amphibious task force commander may assign to each attack group commander responsibility for control of naval gunfire in his landing area, retaining only over-all direction as it applies to the operation as a whole. (When attack groups are formed and separate landing areas are designated, each attack group commander is normally assigned the responsibility for the control and coordination of supporting arms in his landing area.)
- (4) *Shift of responsibility for control to landing force commander.* When the landing force commander establishes the necessary facilities ashore, responsibility for the control of naval gunfire may be passed to him. He is then authorized to assign naval gunfire support missions directly to the fire support ships and to supervise the execution of these missions. In the case, the amphibious task force commander (or his designated subordinate) retains responsibility for—
 - (a) Allocation of available ships for fire support duties.
 - (b) Ammunition resupply and logistic support of fire support ships.

(c) Operational control of fire support ships.

b. Landing Force (Corps) Naval Gunfire Officer. The landing force (corps) has a naval gunfire officer (normally an artillery officer) with one or more naval officers as assistants and the necessary communication personnel. His duties are to advise the landing force commander on naval gunfire matters, to prepare requests for naval gunfire support, and to consolidate requests from lower echelons. These requests are combined to form the landing force naval gunfire requests. He assigns missions to the general support ships of the landing force and helps to coordinate naval gunfire with air and artillery support.

c. Division Naval Gunfire Officer. The duties of the division naval gunfire officer (normally an artillery officer) are the same as those for the corps naval gunfire officer (*a* above). He has one or more naval officers as assistants and the necessary communication personnel. He assigns missions to the general support ships of the division and helps to coordinate naval gunfire with air and artillery support.

d. Naval Gunfire Liaison Officer. At brigade level control of naval gunfire is accomplished by a naval gunfire liaison officer (NGLO) (a naval officer) and the necessary communication personnel. The naval gunfire liaison officer advises the unit commander on naval gunfire matters. He consolidates and passes on fire requests, controls the assignment of general and direct support ships, and coordinates naval gunfire with air and artillery support.

e. Shore Fire Control Party. Each major combat element will be assigned a shore fire control party. The shore fire control party is formed of two teams.

- (1) The naval gunfire liaison team consists of a naval gunfire liaison officer (a naval officer) and necessary Army communication personnel. The naval gunfire liaison officer advises the maneuver battalion commander on the use of naval gunfire. He supervises the spotter (forward observer) and coordinates naval gunfire with artillery and air support.

- (2) Naval gunfire spotting teams consist of a spotter, an assistant spotter, and the necessary communication personnel. The spotter should be an artillery officer assigned by division artillery for the sole purpose of adjusting naval gunfire.

f. Other Spotters or Observers. Any spotter or observer who is familiar with the basic principles of naval gunfire support and has a means of communicating with the landing force may call for and adjust naval gunfire. Calls for fire normally must be processed through the fire support coordination agency of the lowest echelon that has the means for relaying messages between the observer and the supporting ship.

g. Diagram of Control Agencies.

Amphibious task force-----	Gunnery officer (Navy)
Landing force (corps)-----	Naval gunfire officer (Artillery)

Division-----	Naval gunfire officer (Artillery)
Brigade-----	Naval gunfire liaison officer (Navy)
Battalion-----	(Same)
Rifle company-----	Artillery forward observer (through relay); Naval gunfire spotter (direct) (Navy).

9. Terminology

Terminology prescribed for adjusting field artillery will be used by Army observers when they are acting as spotters for naval gunfire except as listed below and in the following sections of this appendix.

Salvo. Term used to indicate number of times one weapon fires. Similar to the term volley in artillery.

Spot. To determine, by observation, deviations of gunfire from the target for the purpose of supporting necessary information for the adjustment of fire.

Section II. COMMUNICATIONS

10. General

Landing force naval gunfire communications are established to provide for the control of the fires of the ships in support of the troops, and for the administrative control and tactical planning of naval gunfire in support of the landing force. Naval gunfire control and administrative nets are established by the naval forces. Requirements for frequencies necessary for naval gunfire support of the landing force are determined by the landing force naval gunfire officer and are requested from the Navy by the landing force communications officer.

11. Communication Nets

a. Conduct of Fire Nets. There are two nets directly assigned for controlling the fires of the ships—the Battalion Shore Fire Control Spotting Net and the Naval Gunfire Air Spot Net.

- (1) Battalion Shore Fire Control Spotting Net. This net is a closed circuit net in that it includes only the direct support ship, the naval liaison officer of the

SFCP, and the spotter. The liaison officer, operating from the command post of the supported maneuver battalion is net control. Conduct of fire is controlled by the Marine spotter from an observation post. Every call for fire is monitored by the liaison officer in the command post of the maneuver battalion. Missions can be cancelled by the liaison officer if they conflict with the employment of other supporting arms or are cancelled on order of the maneuver battalion commander.

- (2) Naval Gunfire Air Spot Net. This net serves primarily the same purpose as does the battalion shore fire control spotting net. If the air spotter is assigned to control the fires of a direct support ship, he fires in the zone of action of the supported unit, and his calls for fire are monitored by the battalion liaison officer. In this case, the air spotter, the liaison officer and the

direct support ship are on this net. The naval gunfire spotter of the battalion shore fire control party can enter this net when directed or as required, but is not necessarily a station on this net at all times. If an air spotter is assigned to fire a general support ship in support of a maneuver battalion, the general support ship also enters this net, but net control is retained by the naval officer at the maneuver battalion. General support ships are authorized to fire at targets of opportunity located in their assigned zones of responsibility, and may employ the service of air observers for these missions. Such missions are monitored by the brigade naval gunfire liaison officer to preclude the possibility of danger to friendly troops.

b. Administrative and/or Tactical Planning Nets. The Force Naval Gunfire Support Net established when the landing force consists of two or more divisions, is guarded by the landing force naval gunfire officer (net control) division naval gunfire officers and the fire support ships in general support of the force. Brigade Naval Gunfire Liaison Officers may enter this net in an emergency. The Division Naval Gunfire Support Net, which is established for a division(s), provides communications between the division naval gunfire officer (net control), brigade naval gunfire liaison officers, and ships in general support of respective units. There is no naval gunfire radio net established between the brigade naval gunfire liaison officers and the SFCs at the maneuver battalions. Communication is primarily by radio relay using the maneuver elements system, or by radio using the nets of the other supporting arms representatives.

c. Local Nets. Additional local nets may be established depending upon the need. A short fire control party local net may be established between the liaison officer and the spotter or may be employed between the spotter and his primary radio when he must occupy a tactical position separated from it.

12. Army Communication Nets

Forward observers, air observers, and other observers send calls for naval gunfire over existing Army nets to the Fire Direction Center/Fire Support Coordination Agency.

13. Call Signs and Frequencies

Call signs and frequencies for spotters, liaison officers, and fire support ships will be prescribed in the operation plan or order. It is mandatory that each ship, naval gunfire spotter, and liaison officer be furnished with a list of call signs and frequencies assigned to all naval gunfire activities. This will permit a more flexible plan for the use and assignment of firing ships.

14. Procedure

Standard communication procedures may be abbreviated if this does not cause confusion. These abbreviated procedures may include—

- a. Elimination of call signs after the call for fire.
- b. Limited use of procedural words and phrases.
- c. A short-phrase, repeat-back method of transmission, accomplished without special operating instructions, such as "Read back," etc.
- d. Divergence from the normal or abbreviated normal message format.

15. Codes and Ciphers

Codes and ciphers to be used for security purposes will be prescribed in the operation plan or orders. In selecting and designating the codes and ciphers to be used by spotters and liaison officers, the possibility of capture or compromise must be considered.

16. Authentication

The system of authentication to be used in naval gunfire nets will be prescribed in the operation plan or order. Because of the possibility of deception by enemy radio stations, which could result in the shifting of fire onto friendly troops, detailed instructions must be issued for the use of authentication.

17. Naval Gunfire Support Brevity Code

A classified brevity code is used in communication transmissions for naval gunfire support. This code will vary from fleet to fleet. If code units other than those indicated are used, the appropriate group must be added to the code list.

a. A forward observer normally sends a call for naval gunfire to the artillery fire direction center. The call for fire is then transmitted to the supporting ship through the naval gunfire

liaison officer. The naval gunfire liaison officer acts as a relay between the observer and the ship throughout the mission. The forward observer may call for naval gunfire through a naval gunfire spotter when both are at the same location.

b. An air observer will send calls for naval gunfire to the fire direction center with which he normally maintains communication. The naval gunfire liaison officer at the fire direction center relays the mission to the supporting ship.

Section III. INITIAL FIRE REQUEST

18. General

a. The initial fire request normally will include the following elements of information and will be transmitted in the sequence indicated (unnecessary elements may be omitted):

- (1) Call.
- (2) Target number.
- (3) Bearing of spotting line.
- (4) Location of target.
- (5) Description of target.
- (6) Danger to friendly troops.
- (7) Number of guns for adjustment and armament required.
- (8) Ammunition.
- (9) Fuze.
- (10) Control of fire.

b. In the initial mission fired by the observer with a particular ship, the observer will specify the unit of measure (meters or yards) to be used.

19. Call

The call is made in accordance with standard communication procedure, and the call signs effective for the operation are used.

20. Target Number

Target numbers are allotted in accordance with the system of numbering designated in operation orders. Announcement of the target number serves to warn the ship that firing on a target is desired immediately.

21. Bearing of the Spotting Line

The spotter selects a spotting line in relation to which he will make sensings and corrections in adjusting the fire. This spotting line may be the observer-target (OT) line, the gun-target (GT) line, or any other reference line that the spotter can readily identify on the ground. A compass or other direction-measuring instrument or a map may be used to determine the bearing of the spotting line. In the absence of these, the spotter must estimate the bearing. The bearing is expressed in mils or degrees and as true, magnetic, or grid.

a. *Observer-Target Line.* A ground observer normally uses the observer-target line as the spotting line. To announce this element he might send BEARING 100 MILS MAGNETIC.

b. *Gun-Target Line.* When a ground or airborne spotter is using the gun-target line as a spotting line, he sends BEARING GUN-TARGET LINE. The ship informs the spotter of the gun-target bearing and subsequently informs him whenever the bearing alters by more than 10°.

c. *Other Reference Lines.* A spotter may use a reference line other than the observer-target line or gun-target line for ease of spotting; for example, a line from a prominent feature on the ground to the target or an imaginary line through the target parallel to a straight road running close to the target. In announcing the bearing of such a line, the spotter uses the direction away from friendly troops toward the enemy.

22. Location of Target

The spotter may give the location of the target in any manner that is clearly understandable and should always include the altitude of the target in feet, meters, or yards. (Unless otherwise specified, the unit of measure for altitude will be feet.) Usual methods for the spotter to give location of a target are—

- a. Giving the coordinates of the target or adjusting point, using the designated grid reference system.
- b. Giving the polar coordinates to the target from a reference point, the chart location of which is known to the ship.
- c. Shifting from a target being fired on to a fresh target, provided the fresh target is within 1,000 meters of the target being fired on and that END OF TARGET has not been ordered.

23. Description of Target

The spotter must describe the target in sufficient detail to permit evaluation by the firing ship.

24. Danger to Friendly Troops

When friendly troops are within approximately 1,500 meters of the target, the warning DANGER followed by the direction of friendly troops from the target and their proximity (in meters) to the target is sent by the spotter. If gunfire is required within 600 meters of friendly troops, the order CLOSE is added after DANGER; e.g., DANGER, CLOSE, SOUTH 500.

25. Number of Guns for Adjustment and Armament Required

The spotter normally signifies the number of guns he recommends for use during adjustment and the armament to be used.

26. Ammunition

The spotter specifies the type of ammunition desired by sending ARMOR PIERCING, HIGH CAPACITY, ILLUMINATING, or SMOKE. If the spotter does not specify a particular type, the firing ship will use high capacity.

27. Fuze

The spotter specifies the type of fuze desired by sending FUZE DELAY, FUZE TIME, or FUZE VT. If this element is omitted from the call for fire, the firing ship will use fuze quick.

28. Control

The spotter always specifies the method of control of fire. He may change the method of control during any single adjustment. The following terms are used to indicate the desired method of control:

a. *Will adjust*—The spotter controls the fire and is responsible for the adjustment. He announces corrections with relation to the spotting line. In the ship, these are converted to corrections with respect to the gun-target line and are then applied to the armament.

b. *Will observe*—The spotter observes and reports the location of the fall of shot in relation to the target. The ship is responsible for adjustment based on the information provided by the spotter.

c. *Ship will adjust*—The spotter designates the target, but spotting and adjustment are carried out by the ship.

d. *Cannot observe*—The spotter is unable to observe and adjust the fire but believes a target exists at the indicated location and that it is of sufficient importance to justify firing on it without adjustment.

e. *At my command*—The spotter desires to regulate the time of firing salvos. This is announced as a preface to the method of control; for example, AT MY COMMAND, WILL ADJUST. When the spotter is airborne, AT MY COMMAND, will always be used.

Section IV. ADJUSTMENT PROCEDURE

29. General

Adjustment is carried out relative to the spotting line. Line adjustment is done by correcting to the spotting line; range adjustment, by the process of bracketing. Corrections are made to adjust time fuze to the desired height of burst. The procedures used and considerations involved in the adjustment of naval gunfire are essentially the same as those for field artillery fire.

30. Reports to the Observer Prior to Firing

The ship will make the following reports to the observer prior to firing when appropriate:

a. Delay. The term "delay" indicates that the ship is not ready to fire. DELAY is followed by an estimate of time in minutes. If sent during an adjustment, it is subsequently followed by READY.

b. Ready. The term "ready" indicates that the ship is ready to fire. For the first salvo, READY is always announced, followed by the time of flight in seconds; the ship then awaits the spotter's order to fire. For subsequent salvos, READY is transmitted only if AT MY COMMAND or DELAY has been announced, in which case the time of flight is omitted.

c. Bearing of the Gun-Target Line. The ship reports the bearing of the gun-target line, as soon as it is known, by announcing GUN-TARGET LINE (so much).

d. Noncompliance with Spotter's Call for Fire. Any action by the ship which is not in accordance with the call for fire must be reported to the spotter. This report may include such items as the use of secondary armament or of ammunition other than that requested.

e. Location of the First Salvo. When DANGER is included in the call for fire, the location of the first salvo is reported in the form FIRST SALVO AT (coordinates or bearing and distance in meters or yards from indicated target location).

f. Vertex Height. The vertex height (maximum ordinate) must be reported by the ship if the spotter is airborne.

31. Opening Fire

Fire normally is opened with two or more guns, depending on conditions of visibility and the caliber of the guns. The term "shot" is announced at the moment of firing. The term "stand by" is announced 5 seconds before a salvo is due to land. These terms are transmitted every time a salvo is fired, except during fire for effect when they are sent only for the first salvo.

32. Line Adjustment

If the first salvo does not fall on, or close to, the spotting line, a correction of the size necessary to bring the next salvo to the spotting line is made. This correction is transmitted as RIGHT (LEFT) (so much) in meters or yards.

33. Height of Burst Adjustment

When fuze time is being used, the spotter adjusts height of burst by transmitting UP (DOWN) (so much) in meters or yards.

34. Range Adjustment

a. As soon as a salvo can be sensed positively for range as over or short, a bracket is commenced along the spotting line. Range corrections should be in the amount of 800, 400, 200, or 100 meters (yards) whichever is necessary to insure a bracket. Once established, a bracket is reduced by further corrections until a 100-meter (yard) bracket, or its equivalent (*c* below), has been obtained.

b. If the correction required to bring the initial salvo to the target is greater than 800 meters (yards), the spotter announces the required correction and the firing ship checks the solution. If no error can be found, the announced correction will be applied by the firing ship.

c. The equivalent of a 100-meter (yard) bracket is obtained in the following cases:

(1) A target hit.

(2) A straddle with a multigun salvo.

d. Range dispersion (100 to 400 meters) is an important factor affecting bracketing, since

it is about 4 times greater than that for line (deflection) dispersion.

e. A range correction is transmitted as ADD (DROP) (so much) in meters or yards.

f. If no range correction is desired, the spotter announces REPEAT.

35. Corrections for Ammunition and Fuze

During adjustment, the spotter may request a change in ammunition or fuze by announcing the type of ammunition or fuze desired.

36. Other Reports by the Spotter During Firing

In addition to sending adjustment corrections and requests for change in ammunition and fuze, the spotter may send other reports to affect the time of firing or to provide information to the firing ship. Such reports may include any of the following terms:

a. At MY COMMAND may be used at any time to control the time of firing. The ship must then report READY to the spotter and await the spotter's order to fire for each salvo.

b. WHEN READY cancels AT MY COMMAND.

c. CHECK FIRE is used to interrupt firing temporarily.

d. GO ON cancels CHECK FIRE.

e. TARGET is sent when a salvo falls on the target.

f. STRADDLE is sent when a multigun salvo straddles the target. It may be followed by a more detailed report giving a correction to move the mean point of impact (MPI) to the target.

g. MIXED is used when the ship is adjusting height of air burst. It indicates that the salvo is correctly adjusted for height of burst and contains both air and impact bursts, the largest proportion of which are in the air.

h. LARGE SPREAD is used to indicate that the spread is excessive.

i. TREND is sent if salvos are observed to be creeping off the target and is followed by an indication of direction; for example, TREND SOUTHWEST.

j. LOST is sent if a salvo is unobserved. The ship will take appropriate action to make the next salvo visible either by applying a correction calculated to bring the next salvo into the spotter's field of view, or, if visibility is bad, by firing a multigun salvo or a smoke shell. The spotter may be able to judge the location of lost bursts by sound, in which case he may send LOST followed by a correction.

k. FRESH TARGET is used to indicate a new target and is followed by an abbreviated call for fire in which the location is given by coordinates or by a shift from the target being engaged. If coordinates are used, the ship converts the difference between the old and the new coordinates and applies that difference to the armament. Any difference in height will be reported as UP (DOWN) (so much). "Fresh target" procedure insures that the information gained from previous adjustment is not lost, and bracketing should not be necessary.

37. Reports by the Ship During Firing

a. NEGLECT is the term used to inform the spotter that the last salvo was fired with incorrect settings. The ship immediately will correct the error and fire again unless AT MY COMMAND is in effect, in which case a new report of READY will be made.

b. SHOT and STAND BY are terms which are used as explained in paragraph 7, this appendix.

c. WILL NOT FIRE is the term used to indicate that the ship is not able to fire, for safety or for other reasons. For example, the ship may be under attack.

Section V. FIRE FOR EFFECT

38. General

Fire for effect is begun when a 100-meter (yard) range bracket, or its equivalent, has been obtained, after adjusting the mean point of impact as necessary. The final correction for range usually is one that will split the 100-meter (yard) bracket.

39. Volume of Fire

The volume of fire for effect is determined by the results desired and by the nature of the target. The spotter is best able to determine the caliber and number of guns required to achieve the desired effect. In his fire for effect request, he specifies the number of guns per salvo and the number of salvos required. The final decision as to the number of guns and quantity of ammunition to be used rests with the firing ship, based on policy contained in orders and a requirement for economy in firing naval guns. Since the quantity of ammunition carried in ships is relatively small, it is important that none should be wasted either by engaging unsuitable targets or by expending more than is necessary to achieve the desired result. The comparatively short life of naval guns is another cogent reason for exercising economy.

40. Destruction Fires

Accuracy is of prime importance in executing destruction fires. Destruction is most successfully accomplished when the target is visible from the ship. If the target is not visible from the ship, a ground or airborne spotter should be made available. If the ship is stationary (anchored or stemming a buoy), the destruction will be achieved more quickly. One gun is normally used both in the adjustment and in fire for effect. Fire for effect is continued until the target is destroyed, spotting correction being applied as necessary for each round fired.

44. Mission Number 1

a. The naval gunfire spotter for an assault element is in communication with a destroyer

41. Neutralization Fires

The procedure used for neutralization fires depends on the conflicting demands of speed and accuracy. For engaging such targets as concentrations of troops or vehicles likely to move, speed is the primary consideration. Adjustment should therefore be obtained by bold spotting, and fire for effect should be fired as rapidly as possible. In other cases, accuracy of adjustment and adherence to a time schedule may take precedence over speed. Neutralization is best achieved during fire for effect by firing salvos at irregular, rather than regular, intervals.

42. Repeat Fire for Effect

If the fire for effect initially delivered is insufficient, the spotter should make a correction if necessary and request REPEAT FIRE FOR EFFECT.

43. Termination of Fire

a. RECORD AS TARGET is announced by the spotter after engagement of a target to signify that further fires may be required at a future time. It normally will not be possible for ships to record targets unless at anchor. On receipt of RECORD AS TARGET from a spotter, the ship records the data used. Before engaging the target again, the ship must allow for any change in data, such as a difference in ballistic data or in the initial position.

b. END OF TARGET is the term used to terminate a fire mission. It may be sent by the spotter or the ship. At END OF TARGET the ship's fire control problem ceases to be generated, and further fire cannot be started without fresh adjustment.

c. The spotter gives a brief report of damage assessment and effectiveness fire.

Section VI. EXAMPLES

which is in direct support of the element. Having discovered enemy antitank weapons at coordinates 598600, 800 meters north of friendly

troops, he decides to fire the ship on the target. Bearing to the target measured from a gridded map is 5,460 mils. Observation is good, and the spotter is not personally under fire. Line of fire is approximately parallel to friendly lines. The spotter sends the following initial fire request:

KANGAROO, THIS IS KIDNEY
TARGET NUMBER 1357
BEARING 5460 MILS GRID
COORDINATES 598600
HEIGHT 120
ANTITANK WEAPONS
DANGER, SOUTH 800
2 GUNS—MAIN ARMAMENT
WILL ADJUST

Ammunition and fuze request are not transmitted since 5-inch AAC (antiaircraft common, a type of HE), normal charge, with time fuze set on SAFE (corresponds to fuze quick in artillery) is the standard load and is satisfactory for this mission.

b. The ship reads back the initial fire request to the spotter and sends the following message:

GUN-TARGET LINE 1200 MILS GRID
FIRST SALVO AT NORTH 800
READY, 25 (time of flight).

c. The spotter announces FIRE, and the ship sends—

SHOT . . . STAND BY

d. The ship's first salvo lands 150 meters left of the target, and the spotter is unable to determine whether the salvo is over or short. At this time the spotter's observation is obscured by drifting smoke. In order to bring the impact to the observer-target line and provide for intermittent observation, the spotter announces—

RIGHT 150
REPEAT
AT MY COMMAND

e. The ship reports READY, and the spotter commands FIRE. The next salvo lands 20 meters left of the target and clearly over. The spotter makes a cautions shift since the target is within 800 meters of friendly troops. He sends—

RIGHT 20
DROP 200

f. The ship reports READY, and the spotter commands FIRE. The next salvo lands short of the target and approximately on line. The spotter sends—

ADD 100

g. The ship reports READY, and the spotter commands FIRE. The next salvo lands over and approximately on line. The spotter now has established a 100-meter bracket and a satisfactory line adjustment, so he is ready to enter fire for effect. He transmits—

DROP 50
6 GUNS, 3 SALVOS
FIRE FOR EFFECT
WHEN READY

h. The ship reports SHOT and STAND BY for the first salvo in fire for effect and ROUNDS COMPLETE when all the rounds have been fired.

i. The 18 rounds in fire for effect land in a close pattern around the target and the antitank weapons cease to fire. The spotter sends—

END OF TARGET
FIRE EFFECTIVE
WEAPONS SILENCED

45. Mission Number 2

a. An artillery air observer with a division that has a battleship in general support discovers an enemy tank battalion proceeding towards a friendly beachhead 6 miles away. The head of the column is at coordinates 243962. After sending a FLASH message reporting the presence and location of the tanks, the observer decides to take the head of the column under fire with the main battery of the battleship. He sends the following initial fire request to the division artillery fire direction center:

GOLF BRAVO, THIS IS ALFA DELTA
24

FIRE MISSION FOR KING KONG
BEARING GUN-TARGET LINE
COORDINATES 243962
HEAD OF TANK COLUMN, PROCEED-
ING SOUTH, SPEED 10 MILES
PER HOUR
2 GUNS—MAIN ARMAMENT
AT MY COMMAND, WILL ADJUST

b. The naval gunfire officer relays the initial fire request to the ship and then relays the following message from the ship to the observer:

GUN-TARGET LINE 1540 MILS GRID
VERTEX 1100 FEET
READY, 39

c. The observer commands FIRE, and the ship reports SHOT ... STAND BY. The ship's first salvo lands an estimated 200 meters left and 800 meters short of target. The observer sends RIGHT 200, ADD 800.

d. The ship reports READY.

e. The observer commands FIRE, and the ship reports SHOT ... STAND BY. The second salvo lands an estimated 100 meters left and 200 meters over the target. The observer sends—

RIGHT 100
DROP 200

f. The ship reports READY.

g. The observer commands FIRE, and the ship reports SHOT ... STAND BY. The third round straddles the target and approximately on the gun-target line. The observer sends—

REPEAT
3 GUNS, 3 SALVOS
FIRE FOR EFFECT

h. The ship reports READY.

i. The observer commands FIRE, and the ship reports SHOT ... STAND BY ... ROUND COMPLETE.

j. Target hits are obtained disabling three tanks, and the remainder of the column is dispersing and withdrawing. The observer sends—

RECORD AS TARGET
END OF TARGET
FIRE EFFECTIVE
3 TANKS BURNING, REMAINDER
DISPERSED

k. Ship repeats back—

RECORD AS TARGET
END OF TARGET
FIRE EFFECTIVE
OUT

46. Mission Number 3

A flank element with a light cruiser in direct support is attacking along the coast. The advance is being held up by enemy personnel in a log and sandbag pillbox located at coordinates 134862 which is 400 meters south of the leading elements. The target is visible from the ship. The artillery observer sends the following initial fire request to the artillery liaison officer:

KANE 21, THIS IS KAND 23
FIRE MISSION FOR KANGAROO
COORDINATES 134862
HEIGHT 140
LOG AND EARTH PILLBOX
DANGER, CLOSE, NORTH 400
SHIP WILL ADJUST

The naval gunfire liaison officer relays the fire mission to the ship. The ship will attack the target by direct fire and report the results to the observer through the naval gunfire liaison officer. Bearing, guns and armament, ammunition, and fuze are not required to be announced by the observer.

47. Mission Number 4

An artillery forward observer has adjusted naval gunfire on a target and has fired for effect with good results but has not sent END OF TARGET to the ship. He suddenly observes a number of enemy tanks and infantry approaching in the same general area. He examines the new target, measures the shift required from the last salvo fired on the old target, and sends—

FRESH TARGET
BEARING 5440 MILS GRID
RIGHT 300
ADD 100
5 TANKS AND PLATOON OF INFANTRY
DANGER, SOUTH 1200
RAPID FIRE, 6 GUNS, 5 SALVOS
FIRE FOR EFFECT

APPENDIX V

ARMOR EMPLOYED IN A FIELD ARTILLERY MISSION

1. General

a. Tank guns are not normally used in the field artillery (indirect fire) role. This is due to the high velocity, flat trajectory, and short tube life of tank guns and the small bursting radius of the ammunition. However, under exceptional circumstances, a command decision may be made to employ tanks in an indirect fire role under the operational control of the supporting field artillery. The tank unit may either be attached or given a reinforcing mission. The field artillery unit is responsible for fire control, communication, and survey and when the tank unit is attached, for ammunition, gasoline, rations, and other supplies. Whether attached or reinforcing, the tank unit must retain the capability of immediately reverting to its primary role of direct fire.

b. This appendix deals with the gunnery techniques used when the tank unit is under the control of the field artillery. For information on the mission and the tactical employment of tank units, characteristics of the tank and fire control materiel, and information on direct fire with tank weapons, see the FM 17-series.

2. Ammunition

a. Shell HE and shell WP are available for all tank guns (76-mm, 90-mm, 105-mm, and 120-mm).

b. A typical basic load will include approximately 60 percent HE, 15 percent WP, and 25 percent antitank ammunition.

c. Shell HE and WP are issued with combination superquick and delay fuzes. Combination mechanical time and superquick or concrete-piercing fuzes may be obtained and substituted for the normal fuzes if required.

Note. See TM 9-1901 and table III of this manual for further information on ammunition.

3. Observer Procedure

Field artillery observer procedures as covered in part THREE are used in conducting indirect fire with tanks.

4. Fire Direction

a. *Firing Chart.* Each tank platoon is plotted on the field artillery firing chart, and the range-deflection protractor is numbered in the same way as for field artillery. The temporary deflection index is placed at deflection 3,200. If tank weapon firing tables are not available to the fire direction center, the tank unit normally fires only observed fire in the indirect role. If tabular or graphical firing tables are available, a registration should be conducted, and the deflection index and deflection correction scale should be set up by using the procedures described in chapter 19 of this manual. During adjustment, corrections sent by the observer are plotted by using the target grid as described in chapter 16.

b. *Fire Commands.* Fire commands are sent from the fire direction center to the tank unit fire control officer, who is responsible for tank fire. The elements and sequence of fire commands differ slightly from field artillery procedure. An example of the sequence is shown in the following fire command:

PLATOON
HE
12,000, UP 10
FROM REFERENCE POINT, RIGHT
115
MORTARS FIRING
FIRE

- (1) *Platoon.* The normal method of employing tanks in an indirect fire role is by platoon (five tank guns). To alert (pieces to follow) all five weapons, the command is PLATOON.
- (2) *HE.* The ammunition command is similar to that for field artillery except that the word "shell" is omitted and the fuze is also part of the command; i.e., HE DELAY. If fuze quick is desired, only the shell command is given; i.e., HE. Since all tank ammunition is fixed, no charge command is given.

- (3) *12,000, UP 10.* The range command (12,000) is given to the nearest 100 meters. The elevation to be fired is determined at the tank position. When the target is at a different altitude from that of the tank, an angle of site is computed in mils and included as part of the command (UP 10). Complementary angle of site for high velocity guns is negligible and is ignored. If the artillery fire direction center has tabular or graphical firing tables, an elevation is normally computed instead of range. The command QUADRANT, which includes the angle of site, is sent to the tanks; i.e., QUADRANT 430. The tank weapons may be laid for elevation by using either the gunner's quadrant or the elevation quadrant. Since the range of most tank weapons is limited by their inability to elevate to high angles, it may be necessary either to dig in the rear of the tanks or to place them on a ramp which slopes away from the direction of fire.
- (4) *From reference point, right 115.* The direction command is given in terms of a reference point. In the indirect fire role, the tanks are laid on an azimuth, and this azimuth is considered the reference point. When the tank is laid, the azimuth indicator is zeroed. Changes in direction are given as right or left of the reference point (azimuth on which laid). Aiming posts may be set out and alined on a common deflection, usually 2,600 or 2,800 mils (this is to right front). Since the tank does not have a panoramic sight, the aiming post deflection is merely an offset angle out of the line of fire. During lulls in firing, the aiming posts are used to check tank displacement without the gunner's turning the turret (tube) back to the aiming circle. Since tank units normally zero the gunner's aid between direction changes, the fire direction center personnel must send the difference in deflection to the tank.

For example, a tank platoon is laid on azimuth 1,600, and a deflection index has been placed on the chart at deflection 3,200. The chart deflection to an announced target is 3,085 mils (azimuth 1,715). The direction command to the tank is FROM REFERENCE POINT, RIGHT 115. The turret (tube) is turned 115 mils to the right, and the gunner's aid is zeroed. The chart deflection to the target plot after the observer correction is 3,093 mils (azimuth 1,707). The direction command is LEFT 8. An alternate method of direction control, which has the advantage of minimizing directional errors by the nonadjusting tanks, is to give all direction commands as deflections in the same manner as that used with artillery weapons. Although the azimuth indicator must be zeroed after the tank is laid, the gunner's aid is not moved or zeroed between rounds. The turret (tube) is moved until the reading on the azimuth indicator is the commanded deflection. In the above example, the initial direction command is DEFLECTION 3085. The gunner moves the turret until 3085 is read on the azimuth indicator (fig. 168). The gunner's aid is not zeroed. The next direction command is DEFLECTION 3093. The turret is moved until 3093 is read on the azimuth indicator (fig. 169).

- (5) *Mortars firing.* The nature of the target is announced to the tank unit as a fire command.
- (6) *Fire.* The command to open fire is FIRE. In tank gunnery, this command is the last element in the sequence of fire commands, because the tank gunner is trained to hold his fire until the command FIRE is received.
- (7) *Other fire commands.* Other fire commands used by the artillery not mentioned in the above sequences, which at times would logically apply to the tank unit (e.g., pieces to fire, method of fire) are sent to the tanks in the

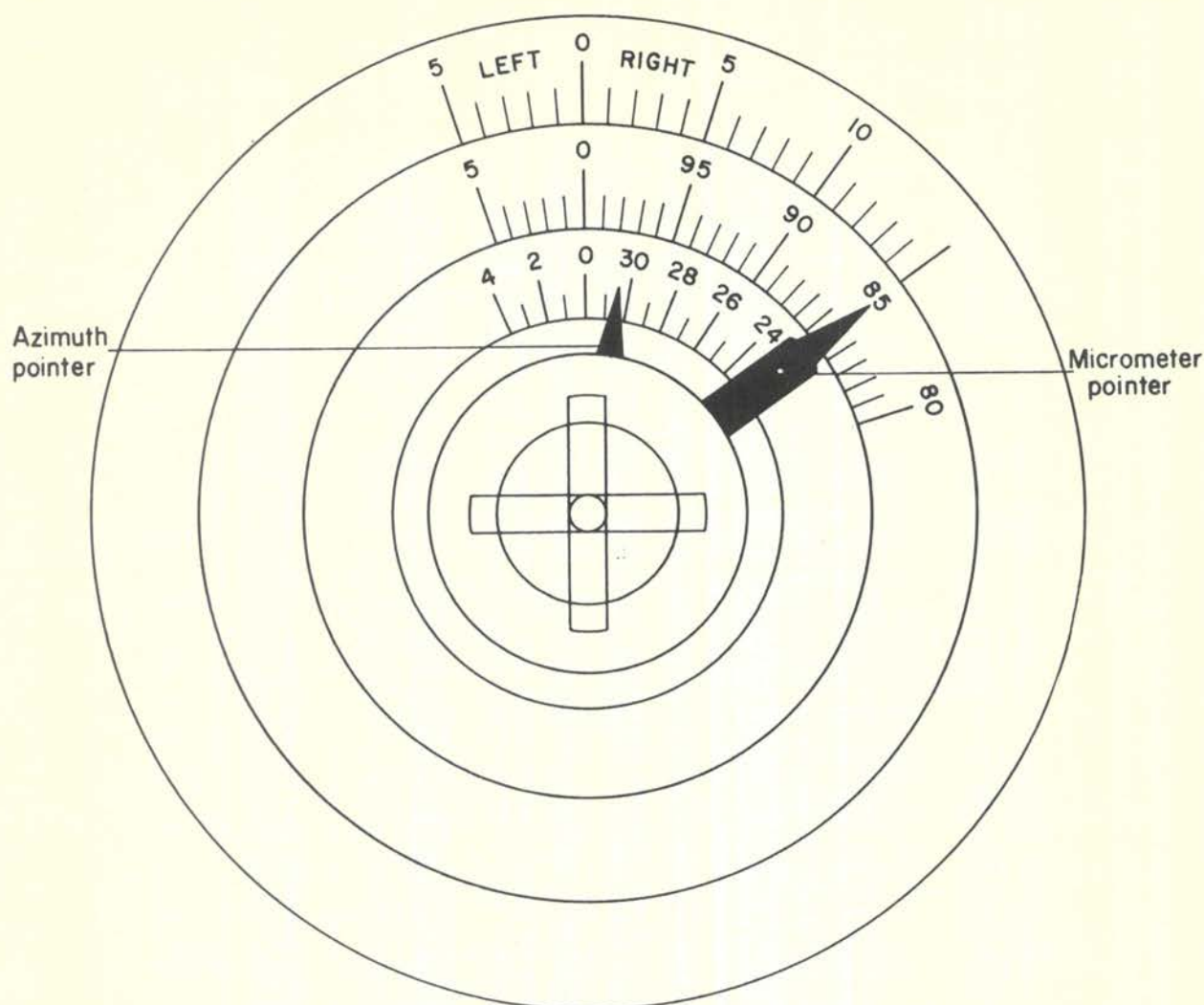


Figure 168. Deflection 3085 on azimuth indicator.

simplest and most understandable manner. Common sense and liaison between artillery and armor should overcome difficulties caused by lack of formal procedure. This problem is further alleviated through the use of prearranged data sheets.

c. Distribution. The normal width of a tank platoon front in the position area is about 150 meters. For tanks armed with 90-mm guns, a parallel sheaf produces an effective pattern of bursts with this position-area width. For tanks armed with guns of other calibers and for position areas of different widths, it is necessary to adjust the width of sheaf in order to obtain the most effective pattern of bursts.

5. Alternate Methods

Other methods which may be employed to control the indirect fire of tanks are—

a. Independent Method. The tank unit uses fire direction equipment and personnel organic to the tank battalion to form, with artillery assistance, a fire direction center.

b. Semi-Independent Method. The tank unit handles its own indirect fire missions from prearranged data sheets. Survey control, met computations, prearranged data sheets, and assistance in laying the tanks may be provided by the supported artillery. Interdiction and harassing missions are the types most effectively handled by use of data sheets.

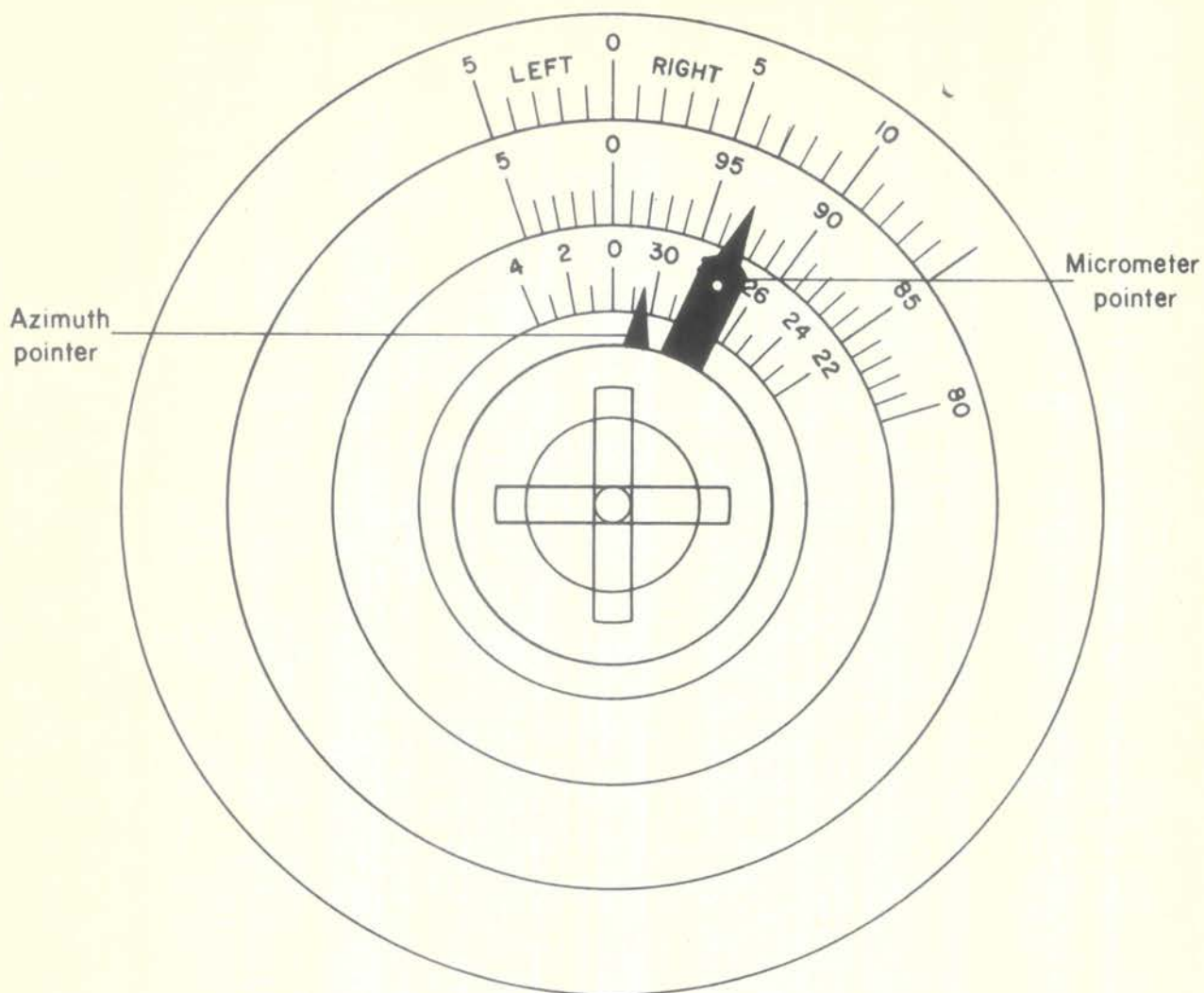


Figure 169. Deflection 3093 on azimuth indicator.

6. Survey

The survey necessary for the indirect firing of the tanks, such as the establishment of their position area location, is made by the field artil-

lery battalion. This is done prior to the arrival of the tanks or as soon after their arrival as possible.

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[AG 353 (16 August 1960)]

By Order of *Wilber M. Brucker*, Secretary of the Army:

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Chief of Staff.

Official:

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For explanation of abbreviations used, see AR 320-50.

TABLE I. CHARACTERISTICS AND CAPABILITIES OF ARTILLERY WEAPONS

*Marine Use Only
**Extended Range
HSW--Horizontal sliding wedge
VSW--Vertical sliding wedge
STIS--Stepped thread, interrupted screw
TIS--Thread interrupted screw
Elec--Electric
Iner--Inertia
PH--Percussion hammer
CP--Continuous pull
SIP--Spring actuated, inertia pull
HPC--Hydropneumatic constant
CHSP--Concentric hydrospring
HPV--Hydropneumatic variable
HP--Hydropneumatic
HS--Hydrospring
MB--Modified box

Caliber and model	Maximum muzzle velocity M/S		Maximum range meters	Length (gun or howitzer) overall inches	Life in full service (rounds)	Type breechblock	Type firing mech	Type recoil mech	Minimum recoil (inches)	Maximum recoil (inches)	Gas pressure at 700	Minimum elevation (mils)	Maximum elevation (mils)	Mils per turn handwheel (mils)	Type traverse	Maximum right traverse (elevation)	Maximum left traverse (mils)	Mils per turn handwheel (traverse)	Type trails	Equilibrators	Brake action	Tire pressure	Panoramic telescope	Telescope mount	Instrument lights	Range or elevation quadrant	Weight, firing (pounds)	Weight, traveling (pounds)	Length, traveling	Width, traveling	Height, traveling	Time to emplace (min)	Maximum rate of fire (rd-min) (first 3 min)	Sustained rate of fire (rd-min)	Prime mover	PM	TM	Weight of projectile (nearest pound)	Weight of complete round (lb)	Max charge	MP--Mule pack Prcht--Parachute 1/4-ton--Jeep 2 1/2-ton--Truck M8--Tractor T10--Transporter 5-ton--Truck 3/4-ton--Truck 10-ton--Truck Hel--Helicopter
75-mm pack howitzer M116	381	8,800	47	20,000	HSW	CP M13	HPC	25	32	1,250	-89	800	24	Axle	53	53	4.1	MB	Spring	Hand	20	M1	M3A1	M13	M1	1,440	1,440	10' 6"	4' 2"	2' 9"	7	8	2.5	Hel MP 1/4-ton	6-78	9-319		14	18		
105-mm howitzer M101A1, towed	472	11,000	101.3	20,000	HSW	CP M13	HPC	39	44	1,100	-89	1,156	10	Pintle	409	400	19	Split	Spring	Hand	40	M12A7D	M21A1	M19	M4A1	4,980	4,980	19' 8"	7'	5'	3	10	3	Hel 2 1/2-ton	6-75	9-3007 9-325		33	42		
105-mm howitzer M102, towed	494 671	11,500 14,800**	131.6	20,000	VSW	CP	HPV	30	50	1,300	-89	1,333	10	Ball Socket	6,400	6,400	20	Box	Pneu	Hand	40	M113	M134	M19	M14	3,100	3,200	21' 6"	5' 11"	5'	4	10	3	Hel Prcht 3/4-ton	6-70	9-1015-234	33 28 **	42			
105-mm howitzer M52A1, SP	472	11,000	99.8	20,000	VSW	SIP	CHSP	11 3/4	13	None	-178	1,156	21	Ring and race	1,066	1,066	21	None	None	Veh	Track	M100	M99		M1	53,000	53,000	18' 10"	10' 6"	11' 1"	1	10	3		6-77	9-7204		33	42		
105-mm howitzer M108, SP	494 671	11,500 14,800**	124		VSW	SIP	CHSP	12	12	None	-106	1,333	10	Ring and race	6,400	6,400	10	None	None	Veh	Track	T177	T208		M15	46,221	46,221	20' 1"	10' 4"	10'	1	10	3		6-79	9-2350-217-10		33	42		
155-mm howitzer M123A1, towed 155-mm howitzer M123A1, aux prop	564	14,600	149.2	15,000	STIS	PH MI	HPV	41	60	1,500	0	1,156	14.8	Pintle	448	418	10.3	Split	Spring	Air hand	55	M12A7C	M25	M34	M1	12,700 13,540	12,700 13,540	24'	8'	5' 11"	5	4	1	5-ton	6-81	9-1025-200-12		95	109		
155-mm howitzer M44A1, SP	564	14,600	156.6	15,000 (est)	STIS	CP M34	HS	19 1/4	19 3/8	None	-89	1,040	F16.1 S2	Ring and race	533	533	6	Veh spade	Tor-sion bar	Veh	Track	M12A7E4	M95	M34	M1	64,000	64,000	20'	10' 8"	10' 2"	1	4	1		6-92	9-7004		95	109		
155-mm howitzer M109, SP	688	18,000	143	15,000 700	TIS	CP M35	HPV	23	36	550	-53	1,333	10	Ring and race	6,400	6,400	10	Veh spade	Hy-draulic gas	Veh	Track	T177	T208		M15	52,461	52,461	20' 1"	10' 4"	10'	1	4	1		6-88	9-2350-217-10		95	109		
155-mm gun M53, SP*	853	23,515	291.7	1,800	STIS	CP M34	HS	18	20	None	-89	1,156		Ring and race	533	533		Veh spade	Hy-draulic gas	Veh	Track	M100	M99C		M1	96,000	96,000	31' 7"	11' 8"	11' 8"	1	4	1			9-2712		96	127		
8-inch howitzer M115, towed	594	16,800	202.5	6,000	STIS	PH M1	HPV	29	70	2,000	-36	1,156	13.1	Pintle	533	533	10	Split	Pneu	Mech air	Bog 45 Lim 65	M12A7C	M18A1	M19 M33 M36	M1	29,700	29,700	36'	8' 4"	9'	20	1.5	0.5	M8 10-ton	6-90	9-3004		200	230		
8-inch howitzer M55, SP	594	16,800	216.7	6,000	STIS	CP M34	HS	18	20	None	-89	1,156		Ring and race	533	533		Veh spade	Hy-draulic gas	Veh	Track	M100	M99C	M33	M1	98,000	98,000	27' 1"	11' 8"	11' 8"	1	1.5	0.5			9-7220		200	230		
8-inch howitzer M110, SP	594	16,800	202.5	6,000	STIS	CP M35	HPV	29	70	2,000	+35	1,156		Ring and race	533	533		Veh spade	Pneu	Veh	Track	M115	M137		M15	58,500	58,500	24' 6"	10' 4"	9' 7"	2	1.5	0.5		6-94	9-2300-216-10		200	230		
175-mm gun M107, SP	914	32,700	422	400	STIS	CP M35	HPV	29	70	2,300	+35	1,156		Ring and race	533	533		Veh spade	Pneu	Veh	Track	M115	M137		M15	62,100	62,100	37' 1"	10' 4"	11' 5"	3	1.5	0.5		6-94	9-2300-216-10		147	198		
4.2-inch mortar M30		5,490								800		1,065		Screw	125	125		Base plate				M34A2	M79	M42	M1	654	654				1 to 3	15 to 20	Prcht 3/4-ton Hel	6-50 23-92	9-2008 9-2009		25				
115-mm multiple rocket launch M91		10,600				Elec				+14		1,066	6.37		178	178	1.9				25	XM53 E2 Unit	XM7	M42	M1	4,240	1,200	12' 8"	7' 6"	5' 11"	30	45 rds in 15 sec	2 1/2-ton	6-54	9-1055-215-12		40	58			

MP--Mule pack
Prcht--Parachute
1/4-ton--Jeep
2 1/2-ton--Truck
M8--Tractor
T10--Transporter
5-ton--Truck
3/4-ton--Truck
10-ton--Truck
Hel--Helicopter

TANK WEAPONS USED IN THE FIELD ARTILLERY ROLE

Weapon	Weight	Time to Emplace (min)	Elevation		Traverse	Range (meters)	Rate of fire--Max (rds/min)
			Min	Max			
Tank, 76-mm gun, M41 (Series)	50,789	1	-73	+351	6,400	14,320	8
Tank, 90-mm gun, M48A2	105,000	1	-160	+338	6,400	18,150	8
Tank, 105-mm gun, M50A1	102,000	1	0	+338	6,400	18,205	6
Tank, 120-mm gun, M103A1	125,000	1	-142	+267	6,400	18,200	4

TABLE II. AMMUNITION CHART

(older fuzes authorized for use are listed in TM 9-1300-203)

WEAPON	DESIGNATION	TYPE	FILLER COMPOSITION	WEIGHT OF PROJECTILE AS FIRED (lbs)	WEIGHT OF COMPLETE RD (MAX CHARGE)	HOW SHIPPED	FUZES				REFERENCES	REMARKS
							PD (POINT DETONATING)	BD (BASE DETONATING)	MTSQ MECH. TIME SUPER QUICK	PROXIMITY (VT)		
75-mm Howitzer	Cartridge, M48	HE	TNT	14.7	18.2	Fuzed	M557 M78(series)		M564 (series)	M513 (series)	TM 9-1300-203 TM 9-319 FT 75-I-4	Issued Fuzed with PD Fuze. SM 9-5-1315
90-mm Gun M47 & M 48	Cartridge, M71A1	HE	Comp B	23.4	42.4	Fuzed	M535 M557		M520 (series)	M513 (series)	TM 9-1300-203 TM9-2300-200-12	See TM 9-1300-203 for fuzes used in the antitank role.
	Cartridge, M313C	Smoke	WP	23.6	40.1	Fuzed	M48A3 M557				TM 9-7022 SM 9-5-1315	
105-mm Gun M60	Cartridge, M393-A1	HEP-T	Comp A3	24.1		Fuzed		M534			TM 9-1300-203 TM9-2350-210-10 SM 9-5-1315	Complete weight not available
105-mm Howitzer (All)	Cartridge, M1	HE	Comp B	33.0	42.0	Fuzed	M557 M78A1		M564 (series)	M513 (series)	TM 9-1300-203 TM 9-325	Ammunition issued for training may be issued fuzed or unfuzed. When issued fuzed (HE) will be issued with PD Fuze. M508 PD Fuze can also be used.
	Cartridge, M314(series)	Illuminating	ILLUM	34.9	43.9	Fuzed			M501 (series)		TM 9-7204	
	Cartridge, M60	GAS	H or HD	33.9	42.9	Fuzed	M557				TM 9-2350-217-10	
	Cartridge, M360	GAS	GB	35.40	44.4	Fuzed	M557 M508				SM 9-5-1315 FT 105-H-6 FT 105-AS-1	
	Cartridge, M84 (series)	Smoke, HC and Colored BE	HC	32.9	41.9	Fuzed			M501 (series)			
			RED	30.7	39.7							
			YELLOW	30.3	39.3							
			GREEN	31.5	40.5							
	Cartridge, M60	Smoke	WP	34.80	43.8	Fuzed	M557					
	Cartridge, M67	HEAT HEAT-T	Comp B	29.3	37.1	Fuzed		M62A1 M91A1				
Cartridge, M327	HEP HEP-T	Comp A3	23.4	33.4	Fuzed		M62 M91					
M102 and M108 only	Cartridge, HE, M482	HE	Comp B	28.5	39.0	Fuzed	M557					
120-mm Gun M103A1	Projectile, M73	HE	TNT	50.0	99.7	Fuzed	M507		M506		TM 9-1300-203	Also can use M535 and M78 (series) Fuzes. Also can use M508 and M535 PD Fuzes.
	Projectile, M356	HE-T	Comp B	50.4	88.7	Fuzed	M557		M564 M520(series)		TM 9-2350-214-10 SM 9-5-1315	
	Projectile, M357	Smoke	WP-T	50.4	88.7	Fuzed	M557					
155-mm Gun M53	Projectile, M101	HE	TNT	95.0	126.6	Unfuzed	M557		M564 M520(series)	M514 (series)	TM 9-1300-203 TM 9-350 TM 9-2300-250-12	
	Projectile, M104	Smoke or Gas, HD	Smoke	98.2	129.8	Unfuzed	M557				SM 9-5-1320	
			HD	92.7	124.3	Unfuzed	M508 M535				FT 155-Q-2	
Projectile, M122	Gas	GB	100.0	131.6	Unfuzed	M508						
155-mm Howitzer (All)	* Projectile, M107	HE	TNT	95.0	100.8	Unfuzed	M557		M564 M520(series)	M514 (series)	TM 9-1300-203 TM 9-331B TM 9-7004	*Also authorized for use with 155-mm gun using normal charge only. M508 and M535 PD Fuzes may also be used.
	* Projectile, M110	Gas	H or HD	98.5	112.1	Unfuzed	M557				TM 9-2350-217-10	
	* Projectile, M121A1	Gas	GB or VX	101.8	115.4	Unfuzed	M508			M514 (series)	SM 9-5-1320 TM 9-1025-200-12	
	* Projectile, M110	Smoke	WP	97.5	115.2	Unfuzed	M557				FT 155-Q-3	
	* Projectile, M116B1	Smoke, HC and Colored, BE	HC	94.4	108.0	Unfuzed			M501 (series)			
			RED	86.4	100.0							
			YELLOW	86.4	100.0							
			GREEN	86.4	100.0							
	* Projectile, M118(series)	Illuminating	ILLUM	100.0	113.6	Unfuzed			M501 (series)			
* Projectile, XM454	Atomic		120.0									
175-mm Gun M107	Projectile, 437	HE	TNT	147.0	202.0	Unfuzed	M572				TM 9-1300-203 TM 9-2300-216-10 FT 175-A-0 (Rev II)	
8-In Howitzer (All)	Projectile, M106	HE	TNT	200.0	228.3	Unfuzed	M557		M564 M520(series)	M514 (series)	TM 9-1300-203 TM 9-3004	
	Projectile, M424	Spotting	TRITONAL	242.0	272.0	Unfuzed			M543 (MT only)		TM9-2300-250-12	
	Projectile, M422	Atomic		242.0	272.0	Unfuzed			M542		TM 9-5-1320 FT 8-J-3	
	Projectile, M426	Gas	GB or VX	200.0	228.3	Unfuzed	M508			M514 (series)	FT 8-0-3	

Table XIII. Typical Targets and Suggested Methods of Attack

Type of target	Type of adjustment	Weapon	Shell	Fuze	Type of fire	Remarks
Armored vehicles (rendezvous).	Observed	All (pref 155-mm or larger).	HE, HEAT	VT, ti, Q	Neutralization, Destruction, Assault.	(1), (2), (3).
Armored vehicles (moving).	Observed	All (pref 155-mm or larger).	HE, WP, HEAT	VT, ti, Q	Neutralization, Destruction, Assault.	Shell HE to force tanks to "button up." Fire of sufficient intensity may demol- alize and break up attack. WP may obscure adjustment. ² Air bursts against personnel manning boats. Destruction by direct fire. Direction of fire preferably with long axis of bridge. Destruction of permanent bridges is accomplished best by knock- ing out bridge support. Fuze quick for wooden or pontoon bridges.
Buildings (frame)	Observed	All	HE, WP	Q	Neutralization	(4).
Buildings (masonry).	Observed	All (pref 155-mm or larger).	HE	CP, delay, Q	Destruction, Neutralization	Several weapons can be converged on one building. In destroying masonry build- ings, the fact that rubble aids defensive fighting and delays friendly mobile ele- ments must be considered. ⁵ Fire should be adjusted at apertures of steel turrets and pillboxes. ⁶ Use high- est practicable charge.
Fortifications (armor).	Observed	All	HEAT, HE (large calibers).	Q	Destruction, Assault, Direct.	Use highest practical charge. (5).
Fortifications (concrete).	Observed	All (pref 155-mm or larger).	HE	CP, delay, Q	Destruction, Assault, Direct.	Use highest practical charge. (5).
Fortifications (earth, logs, etc.).	Observed	All (pref 155-mm or larger).	HE	Delay, Q	Destruction, Assault, Direct.	Use highest practical charge. (5).
Personnel (in open).	Observed	All	HE	VT, ti, Q	Neutralization, Assault, Direct.	TOT missions are most effective. Fuze quick should be fired at lowest practical charge (steep angle of fall gives better fragmentation). Intermittent fire is better than continuous fire. (1).
Personnel (dug in)	Observed	All	HE, WP	VT, ti delay (ricochet).	Neutralization, Harassing, Destruction.	Air bursts are necessary. Surprise not nec- essary. WP is useful in driving person- nel out of holes and into open.
Personnel (in dug- outs or caves).	Observed	All (pref 155-mm or larger).	HE	Delay, Q	Destruction, Assault, Direct.	(5).
Personnel (under light cover).	Observed	All	HE	Q, VT, ti, delay (ricochet).	Neutralization	(4).
Roads and railroads.	Observed	All (pref 155-mm or larger).	HE	Delay, CP	Destruction	Attack critical points: debiles, hills, cross- ings, culverts, bridges, and narrow por- tions. Direction of fire should coincide with direction of road.
Supply installations.	Observed	All	HE, WP	Q, VT, ti	Neutralization, Interdiction, Harassing,	(1), (4).
Vehicles	Observed	All	HW, WP	Q, VT, ti	Neutralization, Destruction.	(1), (2), (4).
Vehicles (rendezvous).	Observed	All	HE, WP	Q, VT, ti	Neutralization, Destruction.	(2), (4), (6).
Weapons (fortified).	Observed	All (pref 155-mm or larger).	HE	Q, CP, delay	Neutralization, Destruction.	Air bursts are desirable if weapon is firing. After weapon is silenced, it is attacked for destruction. Choice of fuze is deter- mined by type of fortification. See fortifications.
Weapons (in open)	Observed	All	HE, WP	VT, ti	Neutralization, Destruction.	(1), (2), (4).

¹ Area is neutralized with shell HE (air bursts if practical). Surprise is essential to produce casualties.

² Material remaining in area should be attacked for destruction by using appropriate shell and fuze.

³ Shell HEAT may be used in fire-for-effect provided that ranges and observing distances are short enough to permit aiming rounds.

⁴ Shell WP should be combined with HE when the target contains inflammable material and the smoke will not obscure adjustment.

⁵ The first objective in firing on moving vehicles is to stop the movement. For this purpose a deep bracket is established so that the target will not move out of the initial bracket during adjust- ment. Speed of adjustment is essential. If possible, the column should be stopped at a point where vehicles cannot change their route and where one stalled vehicle will cause others to stop. Vehicles moving on a road can be attacked by adjusting on a point on the road and then timing the rounds fired so that they arrive at that point when a vehicle is passing it. If available, a battalion or several battalions may fire at different points on the road simultaneously.